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Grain price linkages

see page 1

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In This Issue

A research problem can usually be approached successfully in several different ways. There may be many wrong ways to try to solve a problem, but there is usually more than one right way.

Did you ever wonder how astronomers know how many asteroids orbit the sun? No one has ever been out there to count them, yet we think we have a pretty good idea how many there are. There are many ways to set about estimating the number of asteroids and most of them have been tried. As it happens, several of the methods, each done independently of the others and based on different assumptions, have converged on approximately the same result. Of course, this agreement does not prove any of the estimates correct, but it does increase the likelihood of their being closer to the true number of asteroids than some of the outlying, larger and smaller estimates.

In the early days of ERS, a director of one of the divisions was confronted by what appeared to an observer to be an inefficiency; he was told that people in two different sections of his division were working on the same problem. The director looked at his confronter for a moment and then replied, "Yes, I know. I think that problem is important enough to justify two different people working on it." Unless the two colluded, they were likely to take two different approaches to the problem and, as a result, might together come up with more insights than either could alone.

As a final example, I remember, in the early days of linear programming, how much comfort the modelers of farm management problems took in finding that a computer printout indicated approximately the same solution as one obtained by traditional farm management specialists who used their personal experience, a pencil stub, the back of an envelope, and a bit of artistic skill to solve the same problem.

The articles in this issue find alternative ways to study traditional problems. Grant and others, in the first article, take a new look at the linkages among grain prices in the United States. They use an analytical framework, Granger causality, that has proven useful in situations where statistical tests of causality are wanted. The problem is old and the method is becoming well known. What is new is the application of the method to this problem. The answers aren't surprising. But they are interesting. It is not surprising that a change in corn prices tends to induce subsequent changes in grain sorghum prices. It is interesting to learn that a 1-cent change in the price of corn causes a 0.76-cent change in the price of grain sorghum some 10 weeks later.

Plato and Gordon explain the logic underlying several different algorithms used to analyze the optimality of alternative levels of carryover stocks of grain. They show that some alternatives are equivalent because, although they incorporate slightly different assumptions, they give precisely the same answers. The authors show that some algorithms model the problem more realistically than others, and they recommend that certain features be incorporated in analyses of alternative levels of carryover stocks of grain.

Salathe and others take a fresh look at the demand and price structure for poultry and eggs. They apply standard econometric techniques to a longstanding problem. What is unusual about their approach is that the model of the poultry and egg sector is a subset of a larger model which analyzes the prices and quantities of several other farm commodities. Hence, the authors can study the poultry and egg sector in isolation and can also examine the effects that feedback loops through various crops and livestock sectors have on the prices and quantities of poultry and eggs. This is the third in a series of articles in *Agricultural Economics Research* on FAPSIM, a food and agricultural policy simulation model used extensively in situation and outlook analysis in ERS.

Starting with the April issue, Lorna Aldrich will be the editor of *Agricultural Economics Research.* Lorna brings to the task considerable experience

and skill in economics, mathematics, statistics, and editing. My thanks go to the many authors, reviewers, information editors, editorial board members, graphics designers, and staff assistants, each of whose contributions and help added to my pleasure in serving as your editor these 7 years.

Clark Edwards

Best Article Award

The ERS Administrator's Award for the best article in *Agricultural Economics Research* for the publication year ending April 1982 went to Richard L. Farnsworth and L. Joe Moffitt of the Natural Resource Economics Division. They were honored at a ceremony on December 9, 1982, for their excellence in creative economic analysis and communication in their article, "Biometric Analysis of Pesticide Demand," published in October 1981.

Contents

Grain Price Interrelationships

Warren R. Grant, Anthony Wawa Ngenge, Barton Wade Brorsen, and Jean-Paul Chavas*

Abstract

U.S. grain prices affect one another. This study uses Haugh-Pierce chi-square tests, bivariate autoregressive models, and dynamic multipliers to measure the extent of these effects. Rice prices exhibit very little reaction to changes in other grain prices. However, other grain prices relate closely to one another. Corn and wheat prices tend to significantly affect other grain prices. Feed-grain prices move together as they reflect changing market conditions. Results indicate that the U.S. markets function with a relatively low level of inefficiency.

Keywords

Grain prices, causality, market efficiency, dynamic multipliers

The United States produced about a fifth of the world's grain and contributed more than half of world grain exports during 1978-80; nearly two-thirds of the grain produced in the United States was consumed domestically. Three-fourths of domestic use is for feed, almost one-fifth is for food, and the balance is for nonfood, industrial uses. Rice and wheat are primarily food grains, although 12 percent of domestic wheat use is for feed (*15*). Corn, sorghum, and oats are feed grains, while barley is used both for feed and in breweries. Rye is used both as a feed and a food grain. Corn is the dominant feed grain, followed by sorghum, oats, barley, and rye.

Some relationship should exist between the prices for each grain because of substitutability in production and use. Corn, making up nearly two-thirds of U.S. grain production, should influence other grain prices, especially other feed grains. Wheat, the major food grain, may affect prices of grains competing for food demand. As some wheat is used for feed, wheat prices and feed grain prices may be related.

This study considers the extent to which U.S. grain prices affect one another. It investigates the short-run interactions among these prices by analyzing dynamic adjustments in grain markets. It identifies relationships among prices of related grains and provides some evidence on how fast U.S. grain markets react and adjust to new information.

Data

The data consist of weekly prices of corn, wheat, and sorghum at Kansas City; oats, barley, and rye at Minneapolis; and rice at Houston. The data cover the period from January 1974 to December 1980. All price series are in cents per bushel except rice, which is in cents per 100 pounds. Prices at different locations were used, as prices of all grains at one location were not available. The results should be interpreted in light of these locational differences. Ngenge (*10*) and Brorsen (*4*), using similar methodology, found there were lagged influences across locations.[1] However, they found that prices of the same commodity at different locations were highly related in the current period, indicating that the locational differences were small.

Methodology

The analysis is based on time-series modeling. First, chi-square tests are used to identify the existence

*Grant is an agricultural economist with the National Economics Division, ERS; Ngenge and Brorsen are graduate students at Texas A & M University; and Chavas is an associate professor at the University of Wisconsin.

[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

of relationships among grain prices. The estimation of autoregressive (AR) time-series models then provides a basis for analyzing dynamic price behavior. Calculation of dynamic multipliers from the autoregressive models gives estimates of net impacts that are useful in economic analysis.

In an autoregressive model, $Y(t)$ is a linear function of its lagged values $(Y(t-1)\ldots Y(t-p))$, where p is the length of the autoregressive process. The process can be represented as:

$$Y(t) = \sum_{i=1}^{p} a(i)\, Y(t-1) + e(t) \qquad (1)$$

where $Y(t)$ and $a(i)$ are scalars for univariate time series and $e(t)$ is a serially uncorrected error term (white noise).

The statistical theory of time-series analysis assumes that the series to be investigated is stationary; that is, the mean and covariance are not functions of time (*5*, p. 62). Weekly cash commodity prices have trend components because of inflation, storage costs, and other carrying charges. The first step in the analysis was to filter out the deterministic trend of the series, leaving only stationary stochastic components. A first difference filter was sufficient for all price series, except rice, where a second difference was needed to generate a stationary series.

The extent to which U.S. grain prices affect each other can be partially evaluated by empirical tests of causality. Causality as used in this article refers to Granger's definition; that is, variable x causes another variable y, for a given universe that includes at least x and y, if current values of y can be predicted better by using past values of x than by not using them, other things being equal (*8*). Each price series was further filtered with univariate autoregressive models to reduce the residuals to white noise. We determined the order of the AR models by minimizing Akaike's information criterion (AIC) (*1*). Given the choice of the AR order (p), the univariate AR models and resulting residuals were estimated. To test the adequacy of the AR filters for reducing the series to white noise, we applied Box and Pierce's Q statistic to the residuals (*3*).

$$Q_m = T \sum_{k=1}^{m} r_k^2 \qquad (2)$$

where r_k^2 is the squared estimated autocorrelation of the residuals at lag k; m is a positive integer chosen large enough to include all expected nonzero coefficients; and T is the number of observations. If the AR filters were adequate, that is, if the calculated Q statistic is less than the chi-square value, no autocorrelation should exist in the residuals of each series. Under the null hypothesis of serially independent residuals (of the same series), Q is distributed as a chi-square with $m-p_i$ degrees of freedom, where p_i is the AR order of the i^{th} price series.

Provided that the autocorrelation analysis indicates the absence of serial correlation in the innovations (residuals) of each series, the cross correlations of the innovations of the two series can be analyzed to detect causal relationships between, for example, Y_1 and Y_2 (*9*). These cross correlations at lag k, called $\bar{r}_k$, for k greater than zero, provide an estimate of the impact of Y_1 on Y_2. Similarly, the $\bar{r}_k$ for k less than zero measures the impact of Y_2 on Y_1. Following this reasoning, an overall test of significance for eliciting whether there is joint dependence between two series takes the form of a chi-square statistic (*9, 11, 13*). The hypothesis that two series, Y_1 and Y_2 are independent (written $Y_1 \not\Longleftrightarrow Y_2$) may be rejected at the α level of significance if:

$$U_m = T \sum_{k=-m}^{m} \bar{r}_k^2 > \chi^2_{2m+1}(\alpha) \qquad (3)$$

where $\bar{r}_k^2$ is the squared cross correlation between Y_1 and Y_2 at lag k; m is the number of lags for which cross correlations are computed; and T is the length of the observed time series. The test statistic U_m in equation (3) is distributed as a chi-square with 2m + 1 degrees of freedom.

Similarly, the hypothesis that Y_1 does not cause Y_2 (written $Y_1 \not\Rightarrow Y_2$) may be rejected at the α level of significance if:

$$U_m = T \sum_{k=1}^{m} \bar{r}_k^2 > \chi^2_m(\alpha) \qquad (4)$$

and the hypothesis that Y_2 does not cause Y_1 (written $Y_2 \not\rightarrow Y_1$) may be rejected at the α level of significance if:

$$U_m = T \sum_{k=-1}^{-m} \bar{r}_k^2 > \chi_m^2(\alpha) \quad (5)$$

The empirical use of these Haugh and Pierce tests is not without problems. If relevant variables have been omitted, as is likely in the analysis of many economic time series, one is more likely to identify a feedback structure than a unidirectional system of causation (*2*). Therefore, the identification of a feedback system may be erroneous. A unidirectional flow is generally not subject to this criticism. However, the chi-square tests for unidirectional causality are biased towards failure to reject the null hypothesis of no causation (*13*). They may also be affected by the filters used to obtain the white noise sequences used in the cross correlation analysis. Therefore, the results of the causality analysis should be interpreted with caution. However, causality analysis does provide some useful information concerning the interrelationships among economic time series.

Analysis of causation can be directly related to the efficiency of each market. Assuming that prefiltering (first or second differencing) removes all the deterministic components of the series, then the corresponding residuals should reflect how new information is processed by each market. The univariate AR modeling of these residuals can provide some evidence on market efficiency in the "weak form" sense (7).[2] For example, if residuals are found to behave as an AR model of order zero, the corresponding market would be efficient in the sense that it would adjust instantaneously to the information reflected by its own price.

However, in the case of closely related markets, it is useful to extend this approach by considering several price series simultaneously. For example, when two series are analyzed jointly, the causality tests can provide some evidence on how each market reacts to information reflected by its own as well as other prices. It may be that, while a particular market adjusts rapidly to changes in its own price series, changes in other markets are not so easily assimilated. Causality tests help reveal how a market processes both kinds of information (that is, own efficiency and cross efficiency).

One of the most glaring limitations in the causality tests just discussed is that it is not clear how causation at different lags is to be derived or interpreted. Obviously nonzero cross correlation at any lag implies that that lag has an impact on the current value of the variable in question. However, the meaning of the magnitude of this lagged, nonzero cross correlation is not obvious. When the chi-square tests of the cross correlation of univariate innovations indicate that two variables are not independent, the nature of the dependence structure still needs to be specified. This can be accomplished by further joint analysis of the bivariate short-memory series.

When market efficiency is investigated by means of univariate analysis of price series, the commodity market is studied as if it functioned in isolation. This, however, is hardly the case for any of the U.S. grain markets. It is more likely that the markets for various commodities or for the same commodity at different locations have some influence on one another. If they do, then a market that is considered efficient when studied alone may become inefficient when the relevant information set is expanded to include other price series. Bivariate analysis is a first step towards generalizing the univariate, weak form test of market efficiency as well as for evaluating directly the causal relationships among the commodity prices.

To further investigate the dynamic interactions among grain prices, we fitted selected bivariate AR models to the prefiltered price series. AR orders (p) were determined by use of the AIC criterion. Bivariate autoregressive models using these AR orders were then estimated by seemingly unrelated regression. The bivariate autoregressive model is of the form:

$$\begin{bmatrix} Y_1(t) \\ Y_2(t) \end{bmatrix} + \sum_{j=1}^{p} \begin{bmatrix} a_{11}(j) & a_{12}(j) \\ a_{21}(j) & a_{22}(j) \end{bmatrix} \begin{bmatrix} Y_1(t-j) \\ Y_2(t-j) \end{bmatrix} = \begin{bmatrix} e_1(t) \\ e_2(t) \end{bmatrix} \quad (6)$$

[2] Fama suggests that tests of market efficiency can be carried out based on a division of all information into three sets: (1) a strong form test, which encompasses all information, including that possessed by insiders; (2) a semistrong form test, which includes all publicly available information; and (3) a weak form test, which includes only the information related to historical prices. (7).

where Y_1 and Y_2 are prefiltered versions of two original price series; p is the order of the joint autoregressive scheme, and $e_i(t)$ is a normally distributed disturbance with mean zero and covariance matrix:

$$E[e_i(t)\, e_j(t')] = \begin{bmatrix} 0 & \text{for } t \neq t' \\ \sigma_{ij} & \text{for } t = t';\ i, j = 1,2 \end{bmatrix} \qquad (7)$$

We can then evaluate market efficiency in each market by considering the model one channel at a time. If the efficiency of the first market is of interest, then for channel one:

$$Y_1(t) + \sum_{j=1}^{p} [a_{11}(j)\, Y_1(t-j) + a_{12}(j)\, Y_2(t-j)] = e_1(t) \qquad (8)$$

where $a_{11}(j)$ measures the impact of past values of the first prefiltered price series on its current values. Proved that prefiltering has removed all the deterministic components of the series, then, according to the univariate testing procedure, $a_{11}(j)$ must be zero for all j if this market is efficent with respect to its own past history. Similarly, $a_{12}(j)$ measures the impact of past prefiltered prices in the second market on current values of the first series. The $a_{12}(j)$ must be zero for all j if the market is efficient with respect to information transmitted from the second market. Thus, if the first market is efficient with respect to both sets of information, then $a_{11}(j)$ and $a_{12}(j)$ will be zero for all j. The efficiency of the second market can be evaluated in a similar manner. Hence, we can study the causal structure of the model by examing the matrices:

$$A(j) = \begin{bmatrix} a_{11}(j) & a_{12}(j) \\ a_{21}(j) & a_{22}(j) \end{bmatrix}, j = 1, \ldots, p \qquad (9)$$

For such a bivariate AR(p) process, Granger causality can be evaluated in the following manner: Y_2 does not cause Y_1 if and only if $a_{12}(j) = 0$, for $j = 1, \ldots, p$; and Y_1 does not cause Y_2 if and only if $a_{21}(j) = 0$ for $j = 1, \ldots, p$; and Y_1 and Y_2 are independent if and only if $a_{12}(j) = a_{21}(j) = 0$ for $j = 1, \ldots, p$ (*14*).

When a market is found inefficient, it is worthwhile to study the dynamic properties of the model for that market to understand how long it takes for the impact of changes to be transmitted throughout the market. Beyond the Tjostheim-Haugh-Pierce-Sims procedures for identifying the existence of causality and feedback relationships among time series, it is useful to quantify such relationships to better interpret the impact of one variable on another at different lags. In this research, the dynamic properites of the models were investigated by means of dynamic multipliers (*5*), which measure the reduced form impact of the lagged values of the i^{th} and j^{th} variables on current values of the i^{th} variable. Such multipliers have the advantage of summarizing in a simple way complex interactions that may exist among related price series. Although the intermediate and longrun multipliers were calculated, only the longrun multipliers and their standard errors (*6, 12*) are presented. In an attempt to measure the speed of adjustment, we calculated the number of time periods needed for the intermediate-run multipliers to stabilize within 5 percent of the longrun multipliers. Such information helped provide an economic interpretation of the results.

Results

First, univariate AR models for each U.S. grain price series were estimated. To check whether the corresponding residuals were white noise, we calculated the Q statistics (*1*) (table 1). They indicated that the AR orders selected by the AIC criterion appear appropriate for all series. Given this result, the Haugh-Pierce causality tests were calculated from the AR residuals (table 2). The null hypothesis in table 2 is the case of no causal-

Table 1—Calculated Q statistic applied to residuals from AR filter to each grain price series[1]

Price	Order of univariate AR filter (p)	Calculated Q	Chi-square table value[2]
Rice	17	15.62	19.81
Corn	1	14.91	27.20
Wheat	1	14.73	27.20
Oats	1	26.13	27.20
Barley	1	24.07	27.20
Rye	0	13.82	28.41
Sorghum	5	11.58	22.31

[1] m = 20, except for rice where m = 30.
[2] Significance level = 0.10.

Table 2—Haugh-Pierce chi-square statistics for selected grain prices[1]

Grain price		Null hypothesis[2]			
Series 1	Series 2	Series 1 does not cause series 2	Series 2 does not cause series 1	No instantaneous causality	Independence
Rice	Corn	16.67	18.74	0.00	35.41
Rice	Wheat	27.04**	17.42	0.13	45.59**
Rice	Oats	19.36	11.29	0.11	30.75
Rice	Rye	12.15	6.95	0.00	19.10
Rice	Barley	20.36	15.87	1.72	37.95
Rice	Sorghum	30.14**	16.22	0.15	46.51**
Corn	Wheat	16.97	11.67	69.63***	98.28***
Corn	Oats	17.42	23.39*	36.38***	77.20***
Corn	Rye	27.38**	23.50*	18.62***	69.51***
Corn	Barley	34.45***	9.07	13.25***	56.77***
Corn	Sorghum	24.06*	19.63	165.92***	209.61***
Wheat	Oats	11.61	14.18	33.04***	58.82***
Wheat	Rye	35.52***	12.17	11.83***	59.52***
Wheat	Barley	23.98*	14.56	19.75***	58.29***
Wheat	Sorghum	18.47	9.27	92.90***	120.64***
Oats	Rye	30.15**	14.13	28.44***	72.73***
Oats	Barley	18.58	22.48*	42.79***	83.85***
Oats	Sorghum	17.77	16.24	59.32***	93.33***
Rye	Barley	11.56	27.39**	22.83***	61.77***
Rye	Sorghum	18.76	16.11	21.46***	56.34***
Sorghum	Barley	35.77***	14.20	24.07***	74.04***

[1] m = 15 in unidirectional tests; m = 31 in independence tests.
[2] * = Rejection of the null hypothesis at the 10-percent significance level. ** = Rejection of the null hypothesis at the 5-percent level. *** = Rejection of the null hypothesis at the 1-percent level.

ity or dependence. The causality results suggest that all feed grains significantly influence each other at least instantaneously. The weakest relationships are between rice and other grains; rice exhibits some significant causality on wheat and sorghum. This finding indicates that the price of rice, the only exclusive food grain analyzed here, may not be influenced by feed-grain prices.

Given the Haugh-Pierce causality results, we estimated bivariate AR models after choosing their order using the AIC criterion. To further analyze the dynamic relationships among U.S. grain prices, we calculated longrun multipliers and their standard errors from the bivariate AR estimates (table 3). They provide a basis for measuring own-price and cross-price effects and for identifying the extent to which U.S. grain prices tend to move together.

Rice

Results of the Haugh-Pierce chi-square causal relationship tests indicate no causal relationship between rice and most grains. The null hypothesis that rice prices do not affect sorghum and wheat prices is rejected (table 2). From the bivariate models, the longrun multiplier effect of rice on sorghum is significantly different from zero. However, it is small: 0.058. That is, a 1.0-cent per hundredweight rate of change in the rice price changes the sorghum price 0.058 cent per bushel. None of the other cross-price multipliers is significantly different from zero. This finding suggests that rice prices have only a weak relationship with other grain prices, an expected result as rice, a food grain, offers little direct competition to the feed grains.

Table 3--Longrun multipliers from bivariate AR models

Grain price		Order of AR model	Multipliers[1]				Adjustment period[2]			
Series 1	Series 2		Series 1 on series 1	Series 1 on series 2	Series 2 on series 1	Series 2 on series 2	Series 1 on series 1	Series 1 on series 2	Series 2 on series 1	Series 2 on series 2
Rice	Corn	5	0.328* (.113)	0.021 (.114)	-0.508 (.334)	1.328 (2.72)	12	12	12	6
Rice	Wheat	6	.301* (.018)	.021 (.021)	.086 (.126)	1.386* (.104)	13	16	23	6
Rice	Oats	6	.662* (.026)	-.001 (.004)	-.042 (.456)	1.197* (.079)	5	5	5	2
Rice	Rye	6	.300* (.019)	.026 (.015)	.053 (.082)	1.135 (.114)	13	14	19	7
Rice	Barley	5	.334* (.025)	.004 (.026)	-.191 (.155)	1.311 (.160)	12	17	13	2
Rice	Sorghum	6	.2911* (.023)	.058* (.027)	-.198 (.131)	1.238* (.095)	13	14	11	7
Corn	Wheat	1	1.093 (.077)	.150 (.120)	.108* (.049)	1.169* (.076)	2	3	3	2
Corn	Oats	1	1.140* (.071)	.134* (.052)	.137 (.102)	1.137 (.075)	2	3	3	2
Corn	Rye	2	1.126 (.092)	.429* (.117)	.060 (.054)	.970 (.068)	2	3	3	2
Corn	Barley	1	1.163* (.079)	.323* (.089)	.038 (.074)	1.296* (.084)	2	4	4	3
Corn	Sorghum	6	1.071 (.184)	.759* (.265)	.177 (.186)	.991 (.176)	7	10	10	10
Wheat	Oats	1	1.209* (.083)	.089* (.034)	-.049 (.165)	1.128 (.066)	2	4	4	2
Wheat	Rye	3	1.253* (.100)	.565* (.122)	.088 (.071)	.869 (.106)	3	4	3	5
Wheat	Barley	2	1.266* (.095)	.301* (.111)	-.058 (.114)	1.148 (.127)	3	4	5	3
Wheat	Sorghum	1	1.210* (.100)	.218* (.084)	-.009 (.056)	.933 (.047)	2	3	3	2
Oats	Rye	7	1.023 (1.88)	1.223* (.229)	.140 (.338)	.916 (.314)	7	8	8	7
Oats	Barley	1	1.203* (.103)	.383* (.132)	-.024 (.061)	1.248* (.078)	2	4	3	3
Oats	Sorghum	3	1.058 (.242)	.624* (.200)	.066 (.149)	1.193 (.139)	3	7	6	4
Rye	Barley	2	1.150* (.050)	.071 (.063)	.233* (.066)	1.030 (.086)	3	3	4	3
Rye	Sorghum	0	0	0	0	0	0	0	0	0
Barley	Sorghum	3	1.266 (.171)	2.19 (.160)	.274* (.135)	1.315* (.100)	2	10	9	7

[1] The multipliers express the fraction of a cent change in price i that can be expected in the longrun as a result of a 1-cent change in price j. Standard errors are in parentheses. * = Significantly different from 1(0) at the 5-percent level for own (cross) multipliers.
[2] Weeks required for the intermediate-run multipliers to stabilize within 5 percent of the longrun multiplier.

Corn

The Haugh-Pierce causality tests (table 2) indicate that corn prices lead rye, barley, and sorghum prices. These tests also indicate a joint dependency between corn and all other grains except rice. For corn and wheat the relationship is instantaneous. The longrun multipliers from the bivariate models (table 3) show that a 1.0-cent-per-bushel change in corn price causes a 0.76-cent-per-bushel change in sorghum prices and takes about 10 weeks for the total effect to occur. The impact of corn on barley is less (0.32) and faster (4 weeks). The bivariate AR models and corresponding multipliers indicate significant causal relationships between corn and rye and between corn and oats. They show that although corn prices tend to influence all feed-grain prices, other feed-grain prices do not significantly influence corn prices. This result is expected as corn is the dominant U.S. feed grain. Data in table 3 suggest that of all grain prices, only wheat prices may significantly influence corn prices.

Wheat

The chi-square tests of independence indicate a strong relationship between wheat and all feed grains. Except for rye, however, the cross relationship shows the relationship to be strong only in the current time period. The wheat price series leads the rye price series. Causality tests, both chi-square (table 2) and multipliers (table 3), indicate this. However, the longrun multiplier effect of wheat on rye (0.56) is less than corn on sorghum (0.76). The multipliers show that wheat price is not significantly affected by any other grain prices. This result in not surprising as wheat is primarily a food grain.

Oats

The chi-square tests indicate that oat prices lead rye prices. But no other grain prices lead oats. The chi-square tests for independence point to a strong relationship between oats and all other grains except rice. Again, cross correlations in the current time period are responsible. Multipliers calculated from the AR models verify the lead of oats over rye. It takes about 8 weeks for the 1.22 multiplier effect to occur. The bivariate AR models and corresponding multipliers show that oat prices have a significant impact on barley and sorghum prices.

Barley

Table 2 shows that barley prices lead rye prices, but are led by corn and sorghum prices. The unidirectional chi-square tests indicate no relationship between barley and rice and a weak relationship between barley and wheat and between barley and oats. The chi-square tests for independence are significant for barley against each grain except rice. The cross correlation in the current time period (instantaneous causality) contributes to the significance of this test. The longrun multipliers point to barley's price not influencing most other grain prices (table 3). The only exception is the positive and significant impact of barley prices on rye prices.

Rye

Rye prices are led by corn, wheat, oat, and barley prices (table 2). The multiplier effects of these leads are all significant and take 4-8 weeks to filter through the markets. The results point to rye prices lagging behind other grains. This result is expected given that rye plays a minor role in the U.S. grain market.

Sorghum

Sorghum prices are closely related to corn prices. The chi-square test indicates corn leads sorghum (table 2). There is a very strong instantaneous adjustment as evidenced by the large correlation coefficient in the current time period. The multiplier for a change in corn price on sorghum is 0.76 whereas the multiplier for sorghum on corn is only 0.18, which is not significantly different from zero (table 3). Sorghum prices lead barley prices. Each 1.0-cent-per-bushel change in sorghum price leads to a 0.27-cent-per-bushel change in barley price. The effect of sorghum prices on other grains is marginal and nonsignificant.

Limitations of the Study

This study has several important limitations. One is the effect of locational differences. For example,

our finding that rice prices do not influence corn prices would be more precisely interpreted as rice prices in Houston do not influence corn prices in Kansas City. The Haugh-Pierce univariate causality tests are biased under some conditions. Also, the rice price series was filtered more than the other price series. Second differences were used, and the order of the univariate AR selected was much higher for rice than for any of the other commodities. The fact that the own-price multiplier for rice was the only one significantly less than 1.0 indicates it was filtered more heavily. In spite of these limitations, we believe this study offers considerable insight into dynamic grain price interrelationships.

Conclusions

Using time series modeling, we investigated the dynamic adjustments in U.S. grain prices in the seventies. All grain prices were found to take more than 1 week to adjust to changing market conditions. In that sense, the grain markets are inefficient in the "weak form" (see footnote 2)(7). However, our results suggest that the degree of inefficiency may be low. For example, table 2 indicates that for feed grains, instantaneous causality constitutes a major part of the chi-square test for independence, implying that significant economic adjustments occur within 1 week. The multiplier analysis using bivariate models suggests that the adjustments are completed within a few weeks. Moreover, the explanatory power of all AR models is generally low, implying that their predictive power is expected to be low, and it may not be easy to develop profitable trading rules from the AR estimates.[3] Finally, the non-instantaneous price adjustments identified in this study may reflect the existence of transaction costs (storage costs and others) not taken into consideration by the models. These elements indicate that U.S. grain markets function with a relatively low level of inefficiency.

Our results show how U.S. grain prices influence each other. An important finding is that rice prices exhibit very little reaction to changes in other grain prices, implying that direct competition between rice and other grains is limited.

However, other grain prices are found to be closely interrelated. These relationships indicate that, as expected, the major crop prices (such as corn) tend to significantly affect other grain prices. For example, adjustments in corn prices lead to adjustments in sorghum prices, with the multiplier effect of 0.76 occurring over 10 weeks. Similarly, changes in corn and wheat prices lead to changes in barley and rye prices. Oat prices are found to lead only rye prices, while rye prices tend to follow the lead of corn, oats, barley, and wheat. As expected, feed-grain prices behave as prices of substitute commodities competing for the feed market; the cross-price multipliers are all positive when significant (table 3). Feed-grain prices tend to move together as they reflect changing market conditions.

[3] The coefficients of determination ranged from 0.018 to 0.385.

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Dynamic Programming and the Economics of Optimal Grain Storage

By Gerald Plato and Douglas Gordon*

Abstract

Understanding the dynamic programming algorithms used in the optimal grain storage literature is a prerequisite to understanding the findings of this literature. This article introduces these dynamic programming algorithms by examining several in terms of their underlying economic behavior. These are Gustafson's original algorithms and algorithms developed by Gardner and Ippolito that include rational producer response in addition to optimal grain storage, making them the most advanced in the optimal grain storage literature.

Keywords

Dynamic programming, optimal storage, price stabilization, rational expectations

Grain prices have fluctuated widely since the early seventies. One method of dampening price fluctuations is to store grain in bumper crop years for use in lean years. This possibility has revitalized interest in applying dynamic programming techniques to the analysis of grain carryover. Dynamic programming algorithms determine grain carryover rules that are optimal under specified market assumptions; thus, a common title for this literature is optimal grain storage. This article provides an introduction to the dynamic programming algorithms in the optimal grain storage literature. This literature is growing rapidly because both the objective to be maximized and the market assumptions can be changed to reflect a multitude of types of market situations.

The dynamic programming method determines carryover from one harvest to the next by maximizing a specific objective function, such as the value of grain consumption. The method also accounts for the expected impact of one year's carryover on carryover levels in future years. This consideration makes the carryover determination optimal.

We examine several dynamic programming algorithms from the optimal grain storage literature in terms of the economic behavior of storers (speculators) and producers.

We concentrate on dynamic programming algorithms developed by Gardner (*3*) and by Ippolito (*7*).[1] Their work contains improvements in the incorporation of economic behavior, particularly producer supply response, into the dynamic programming method. We also examine Gustafson's (*5*) original dynamic programming analysis of grain storage—the foundation for the optimal grain storage literature.

The basic dynamic programming algorithm maximizes an objective function, subject to the influence of a random variable. The algorithm accomplishes this by finding a sequence of decisions concerning the levels of a control variable. One type of grain storage problem fits particularly well into this algorithm: the problem of maximizing the value of consumption over a long time period.[2] The control variable is the size of grain carryover from

*The authors are agricultural economists in the National Economics Division, ERS. They thank Clark Edwards, Bruce Gardner, David Harrington, and anonymous reviewers for reviewing a previous draft. They also thank Pauline Ippolito for explaining her algorithm.

[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

[2] The objective of maximizing total expected revenue can be used instead of total expected value of consumption. Maximizing total revenue corresponds to a grain marketing board that acts as a monopolist for the benefit of grain producers. Maximizing total value of consumption corresponds to a competitive grain market.

this year to next year. The decision each year is how much grain to carry into the next marketing year. The random variable in this problem is production. Its variability is largely attributable to the unpredictability of weather.

Gustafson developed a dynamic programming algorithm to find optimal grain carryover levels with random production. Grain carryover is determined given the total grain supply after harvest, which equals current production plus carryover from the previous year. The carryover decisions are made optimally in the sense that the sum of the current value and expected future value of consumption less storage cost is maximized.

Demand variability and forward-looking producer reponse are additional elements needed in a comprehensive dynamic programming algorithm for a grain market. Both these elements influence the optimal grain carryover level for a given level of total grain supply. Including them places optimal grain storage firmly in an economic context, but complicates the dynamic programming computations. Demand variability includes fluctuations in national income. If demand includes export demand, then its variability is also attributable to grain supply variability in other countries.

Forward-looking producer response adds rational expectations to the model. This addition allows producers to react to differing levels of grain carryover and allows speculators to react to differing levels of expected production.

Table 1 shows the objectives maximized and the demand and supply assumptions for the algorithms we examine. The table provides a starting point for understanding the similarities and differences among the algorithms. One maximizes the objective functions of the algorithms by finding the optimal carryover rules and, if production is given

Table 1—Specifications for the optimal carryover algorithms

Algorithm description	Objective maximized	Current year demand	Current year production
Gustafson:			
1A. Random production and a stable demand curve	Value of consumption	Linear function of current year's price	Random variable
1B. Random production and a stable demand curve	Returns from carryover	Linear function of current year's price	Random variable
2A. Random production and a fluctuating demand curve	Value of consumption	Linear function of current year's price plus a random term	Random variable
2B. Random production and a fluctuating demand curve	Returns from carryover	Linear function of current year's price plus a random term	Random variable
Gardner:			
1A. Rational production and a stable demand curve	Economic surplus	Linear function of current year's price	Linear function of current year's expected price plus a random term[1]
1B. Rational production and a stable demand curve	Returns from carryover and returns from production	Linear function of current year's price	Linear function of current year's expected price plus a random term[1]
Ippolito:			
1. Rational production and a fluctuating demand curve	Returns from carryover and returns from production	Linear function of current year's price plus a random term	Linear function of current year's expected price plus a random term[1]

[1] The production response for a particular year is dependent on the expected price for that year in both Gardner's algorithms and Ippolito's algorithm. However, there is a difference in the order of solving for the production response. Gardner's algorithms solve for the current year's carryover and for next year's production. Ippolito's algorithm solves for the current year's carryover and for the current year's production.

as a function of expected price, by also finding the rational production response. Under specific market assumptions, maximizing the value of consumption is equivalent to maximizing the returns from carryover in a competitive market.[3] Furthermore, maximizing economic surplus is equivalent to maximizing returns from carryover and returns from production in a competitive market under these market assumptions. These objectives result in identical carryover rules and identical production responses. To make the explanation easier, we show Gardner's algorithms with a stable demand curve. Gardner included a random demand component using the method pioneered by Gustafson. In this article, we explain Gustafson's method of including a random demand component.

First, we examine a dynamic programming algorithm to find optimal carryover levels under random production and stable demand, using the value of consumption as the objective function. We then show that the first-order condition for maximizing the value of consumption suggests an alternative algorithm based on the objective of maximizing the returns to storers in a competitive market. Next we show how a stochastic demand component is added to these two dynamic programming algorithms. Finally, we examine algorithms that include rational producer response and explain the relationship between rational production response and optimal grain carryover.

Optimal Grain Carryover Under Random Production

One measure of consumer welfare is the area under the demand curve. This measure is a convenient way to put a value on consumption. In this section we examine the dynamic programming algorithm for finding optimal carryover levels using the area under the demand curve as the objective function. In addition, we review the first-order conditions for maximizing the value of consumption. These first-order conditions draw attention to the economic behavior of speculators in grain storage. Profit-maximizing behavior by speculators in a market satisfying specific economic assumptions will bring about competitive equilibrium levels of producer and consumer behavior. We review an alternative algorithm for determining the optimal grain carryover using the grain prices suggested by the first-order conditions. These algorithms were developed by Gustafson, who also extended them to include demand variability.

The first algorithm finds the optimal grain carryover given the level of total supply by a trial-and-error search. Discrete specifications of carryover and total supply are required because the search for the optimal carryover level must be restricted to a finite number of possibilities and the search procedure can only be used a finite number of times. In addition, a discrete specification is required for production as total supply equals carryover from the previous year plus production. The parameters of the first two methods include storage cost, discount rate, variability and mean level of production, and the level (intercept) and slope of the demand equation.

Estimating Optimal Carryovers with Value of Consumption as the Objective Function

The value of consumption algorithm solves for optimal carryovers under random production by the dynamic programming method known as value iteration.[4] It finds the optimal carryover, $C_{k,t}$, for each possible level of the total supply after harvest, $S_{i,t}$; where t is the current year, and i and k denote discrete intervals over the range of values of the variables. The subscript j replaces i to indicate levels of total supply for the next year, $S_{j,t+1}$.

The optimal carryover decisions maximize the value of consumption in year t, $R_{i,t}$, plus the discounted expectation of the value of future consumption, $r \sum_{j=1}^{I} [Pr(S_{j,t+1} \mid C_{k,t})] f_{j,t+1}$, minus the current year's storage cost, $SC(C_{k,t})$. The constant r is the discount rate, which equals $1/(1+\rho)$; where ρ is an interest rate.

Equations (1) and (2) show the computations involved in finding the optimal carryover levels:

[3] See Gustafson (*5*, p. 49) for a succinct review of these assumptions.

[4] The approach used to solve equations (1) and (2) is known as value iteration in the dynamic programming literature. Dynamic programming problems can also be solved by Howard's policy iteration approach (*6*). The value iteration approach is used in all the algorithms of this article.

$$f_{i,T} = \max_{k=1}[R_{i,T} \mid S_{i,T} - C_{k,T}] \quad i = 1,2, \ldots, I \quad (1)$$

$$f_{i,t} = \max_{k} (R_{i,t} \mid S_{i,t} - C_{k,t}) - SC(C_{k,t})$$

$$+ r \sum_{j=1}^{I} [Pr(S_{j,t+1} \mid C_{k,t})] f_{j,t+1} \quad (2)$$

$$i,j = 1,2, \ldots, I$$
$$k = 1,2, \ldots, K$$

where:

$t = T, T-1, T-2, \ldots$	indicates year starting with the most distant year considered (the horizon), year T;
$i,j = 1,2, \ldots, I$	are intervals indicating discrete levels of total supply after harvest in the current year (year t) and in the following year (year t+1), respectively (for example, level i = 2 might represent 10 million bushels);
$k = 1,2, \ldots, K$	indicates discrete carryover levels in the current year (year t);
$Pr(S_{j,t+1} \mid C_{k,t})$	is the probability that total supply next year will be at level j when carryover from the current year is at level k.

The first equation is used in the first (most distant) year considered, year T. Carryout from year T is assumed to equal zero (k = 1) for all possible levels of total supply, implying that we need not consider storage cost and expected value of future consumption. In prior years these terms must be included, so equation (2) is used.

In the optimal grain storage literature, demand is often specified as a linear function of price. Let $D_{i,t}$ represent the following demand curve: $Q^D_{i,t} = \alpha - \beta P_{i,t}$. A linear demand function gives a value of consumption, $R_{i,t}$, in the current year equal to:

$$R_{i,t} = (\alpha/\beta)(S_{i,t} - C_{k,t}) - \frac{(S_{i,t} - C_{k,t})^2}{2\beta} \quad (3)$$

Equation (3) is the integral of the inverse demand function (price as a function of quantity) from zero to q, $\int_0^q (\alpha/\beta - \frac{1}{\beta} q)dq$, where q equals total supply minus the chosen level of carryover. This is the area under a linear demand curve from zero to the level of total supply minus carryover, $S_{i,t} - C_{k,t}$.

The algorithm operates backwards in time from the last year considered, year T. The logic is that the optimal carryover decisions for future total supply levels and the probabilities that these total supply levels will occur must be known prior to making the optimal carryover decision for the current year.

The algorithm starts by using equation (1) to calculate the maximum value of consumption, $f_{i,t}$, for each level of total supply, $S_{i,t}$, in year T, the last year considered. Each of these maximum values has a zero carryover; level 1 of subscript k represents zero carryover. The carryover in the last year considered is usually specified to be zero with the value iteration approach. This restriction does not influence the final results of the value iteration approach as the influence of zero carryover for the last year is gradually dissipated as we move backward in time.

Next, using equation (2), one finds the maximum expected value of consumption in the preceding year, t = T-1, by searching among the K possible carryover levels for each level of total supply, $S_{i,t}$. The values $f_{j,t+1}$; j = 1,. . ., I are the maximums found in equation (1). The term $Pr(S_{j,t+1} \mid C_{k,t})$ is the probability that next year's total supply will be at level j when carryover from the current year is at level k. The probabilities of the various levels of total supply occurring around its mean are determined by the probability distribution of production outcomes.

The mean of this probability distribution equals carryover plus the mean level of production and is determined by the carryover decision:

$$E(\Pr(S_{j,t+1} \mid C_{k,t})) = C_{k,t} + E(PROD_{t+1} \mid C_{k,t}) \quad (4)$$

The expected level of production is the unconditional mean, $E(PROD_{t+1})$, when random production is assumed.

Next, equation (2) is used to find the optimum carryover for the preceding year; this time year $t = T\text{-}2$. The procedure is as previously described for equation (2) except that the maximum values, $f_{j,t+1}$, are those found for year T-1.

Assuming that the parameters in equations (1) and (2) are stable over time, additional years are included until the optimal carryovers (levels of the control variable) converge to a particular level for each level of total supply. At this point, the influence of the zero carryover restriction for year T is completely dissipated. The correspondence between these optimal carryovers and total supply represents the optimal storage behavior (optimum carryover decisions) in a perfectly competitive market. It is optimal because these levels of carryover maximize the current plus the expected future value of consumption minus the storage cost over an indefinite time span. In this situation, this optimal storage behavior (set of carryover rules) remains in effect for each new total supply, that is, for each new harvest until a change occurs in one or more of the parameters.

Gustafson (*5*) developed the preceding algorithm specifically for estimating optimal grain carryover. Howard (*6*) independently developed a similar algorithm to estimate optimal decisions. We recommend Howard's book for further background reading on dynamic programming.

The search for the optimum carryover level (given the level of total supply) is not a brute force search over all possible carryovers. If the optimum carryover level is greater than zero, then the value of equation (2) increases, reaches a maximum, and then decreases as carryover increases (as the welfare measure is quadratic). In this situation, the algorithm evaluates equation (2), using successively larger carryover levels until the maximum is passed. The optimal carryover level is the next to last value used. If the value of equation (2) decreases as carryover increases, the optimum carryover level is zero. This occurs when total supply is low. A value of carryover less than zero might maximize an unconstrained version of equation (2) in this situation, but only zero or positive values for carryover are physically possible. Negative carryover values imply that grain can be borrowed from next year's harvest for use in the current year.

The determination of the optimal current-year carryover by use of equation (2) is an application of Bellman's principle of optimality (*1*, p. 83). This principle states that a necessary condition for the current decision to be optimal is that future decisions must constitute optimal behavior with regard to the effect of the current decision. This rather elusive concept implies that the trial-and-error search for the optimal grain carryover in the current year, given the level of total supply, requires knowledge of how future optimal decisions are affected by the current grain carryover decision. This knowledge is contained in the maximums ($f_{j,t+1}$; $j = 1,\ldots,I$) found in the previous solutions of equation (2).

We can see a profit-maximizing motive for storage by examining the first-order condition for maximizing equation (2). We derived the standard expression for this first-order condition, expression (5.3), by taking the partial derivative of the maximum found in equation (2) with respect to the current year's carryover:

$$\frac{\partial f_{i,t}}{\partial C_{k,t}} = \frac{\partial (R_{i,t} \mid S_{i,t} - C_{k,t})}{\partial C_{k,t}} - \frac{\partial SC(C_{k,t})}{\partial C_{k,t}} + r \sum_{j=1}^{I} (\Pr(S_{j,t+1} \mid C_{k,t})) \frac{\partial f_{j,t+1}}{\partial S_{j,t+1}} \leq 0 \quad (5)$$

$$= -\left[\alpha/\beta - \frac{1}{\beta}(S_{i,t} - C_{k,t})\right] - MSC + r \sum_{j=1}^{I} (\Pr(S_{j,t+1} \mid C_{k,t}))P_{j,t+1} \leq 0 \quad (5.1)$$

$$= -P_{i,t} - MSC + rE(P_{t+1} \mid C_{k,t}) \leq 0 \quad (5.2)$$

so:

$$P_{i,t} \geq rE(P_{t+1} \mid C_{k,t}) - MSC \quad (5.3)$$

where E is the expectations operator and MSC is marginal storage cost.

Expression (5.3) is an equality when grain is stored at the optimal level. In this situation, grain storage is increased and the current year's price, $P_{i,t}$, is bid up by speculators until it equals next year's expected price, $E(P_{t+1} | C_{k,t})$, times the discount factor, r, minus the marginal (per bushel) storage cost, MSC. An increase in grain storage also reduces next year's expected price. The marginal storage cost may either increase or remain constant with larger carryover levels, although it is convenient to assume a constant marginal cost.

The cost of holding each unit equals the purchase price, $P_{i,t}$ plus the marginal storage cost. The expected per unit return from storage equals expected price minus the holding cost. That is, the expected return is $[E(P_{t+1})-(P_{i,t}+MSC)]$ or $[E(P_{t+1})-rE(P_{t+1})]$. Of course, the return for any single year will most likely differ from the average or expected rate.

The first-order condition in (5.3) is an inequality when the optimal decision is to store no grain. In this situation, the current year's price is greater than the discounted value of next year's expected price minus the marginal storage cost. This situation occurs when the grain harvest in the current year falls below a critical level.

Because the link between the standard expression for the first-order condition (5.3) and equation (2) is not fully explained in the optimal grain storage literature, we have included the intermediate steps (5.1) and (5.2). The derivative of the area under the demand curve, $R_{i,t}$, with respect to quantity (in this case carryover, $C_{k,t}$), is the inverse demand curve (first term in equation (5.1)). A minus sign precedes this term as increases in carryover reduce current consumption and, hence, the area under the demand curve. Evaluating the inverse demand function (the first term in (5.1)) at $S_{i,t}-C_{k,t}$ produces the negative of the current year's price, the first term of expression (5.2).

The second term in equation (2) is total storage cost, given the level of carryover. The partial derivative of total storage cost with respect to carryover is the marginal storage cost shown as MSC preceded by a minus sign in (5.1) and (5.2). Marginal storage cost is usually specified as a constant value in the optimal grain storage literature regardless of the level of carryover. However, the total cost of storage function can be specified so that the marginal storage cost increases as carryover increases.

In the third term of equation (2) the derivative of each of the maximums, $f_{j,t+1}$, with respect to next year's total supply, $S_{j,t+1}$, is:

$$\frac{\partial f_{j,t+1}}{\partial S_{j,t+1}} = \frac{\partial R_{j,t+1}}{\partial S_{j,t+1}} - \frac{\partial SC(C_{k,t+1})}{\partial S_{j,t+1}} + r\sum_{\ell=1}^{I} (P_{\ell,t}C_{k,t+1})\frac{\partial f_{\ell,t+2}}{\partial S_{j,t+1}} \qquad (6)$$

which equals $(\alpha/\beta - 1/\beta)(S_{j,t+1}-C_{k,t+1}) - 0 + 0$ or $P_{j,t+1}$.[5] Multiplying each possible price next year, $P_{j,t+1}$, by its probability of occurring and summing over j, as shown in the last term in (5.1), produces next year's expected price for the current year's level of carryover. This expected price is shown in the last term of (5.2). The maximum $f_{j,t+1}$ equals the value of consumption next year if supply turns out to be $S_{j,t+1}$, minus the storage cost associated with this level of supply, plus the discounted expected value of the maximums for year t+2. The index $\ell = 1,2,\ldots,I$ represents the possible levels of total supply 2 years hence and $(Pr(S_{\ell,t+2} | C_{k,t+1}))$ is the probability that total supply 2 years hence will be at level ℓ if supply next year is at level $S_{j,t+1}$. The partial derivative of $f_{j,t+1}$, shown in (5), is taken with respect to next year's total supply rather than with respect to the current year's carryover. This substitution can be made because a given increase in carryover from the current year increases next year's total supply by the same amount.

Nonlinear specifications of demand require integration and differentiation techniques that differ from those shown when a linear specification of demand is used. However, the standard expression of the first-order condition shown in (5.3) is not altered by using a nonlinear specification of demand.

Price Method for Estimating Optimal Carryovers

One can find optimal carryovers by using the first-order condition in (5). The first step is to

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[5] Burt's article (*2*) helped us understand how to take the derivative of $f_{j,t+1}$ with respect to $S_{j,t+1}$.

calculate the price, $P_{i,t}$, for each level of total supply in year T, the last year, by use of the demand equation. As with the value of consumption method, there are no carryovers in the last year. The second step is to calculate the optimal carryover for each level of total supply in the next to last year, year T-1, using expression (5.1). The procedure is to search over the possible carryover levels (given the level of total supply) to determine the carryover level that makes (5.1) equal zero. This may be impossible for low levels of total supply. If equality is impossible, the optimal carryover is zero. As mentioned earlier, an increase in carryover increases the current year's price and decreases next year's expected price. We can calculate the current year's price, $P_{i,t}$ in (5.1) by evaluating the demand function at the given level of total supply minus the chosen level of carryover.

One uses the prices found for year T, the last year, in the last term in (5.1) when searching for the carryover level for year T-1, the next to last year. The probability of each of these prices occurring as well as next year's expected price shown in the last term in (5.2), is determined by the carryover level.

As with the total value of consumption method in equations (1) and (2), additional years are added until the carryover converges to a particular value for each level of total supply. The optimal carryovers are the same as those that one finds using equations (1) and (2).

In this example with random production, there is no computational advantage in calculating optimal carryovers by the price method, that is, by the first-order condition. However, when a random demand component is also included, the price method does offer computational savings.

Optimal Grain Storage When a Random Demand Component is Included

Equations (7) and (8) include a random demand component in addition to random production.

$$f_{i,h,T} = \max_{k=1}[R_{i,h,T} \mid S_{i,T} - C_{k,T}; D_{h,T}]$$

$$i = 1,2, \ldots, I \qquad h = 1,2, \ldots, H \tag{7}$$

$$f_{i,h,t} = \max_{k}\Big\{(R_{i,h,t} \mid S_{i,h,t} - C_{k,t}; D_{h,t}) - SC(C_{k,t}) - r\sum_{j=1}^{I}(Pr(S_j \mid C_{k,t}))\sum_{m=1}^{H}Pr(D_{m,t+1})f_{j,m,t+1}\Big\}$$

$$k = 1,2, \ldots, K \qquad i = 1,2, \ldots, I \qquad h = 1,2, \ldots, H \tag{8}$$

The indexes t, i, j, and k are the same as defined for equations (1) and (2). In addition to these indexes, equations (7) and (8) contain the two indexes $h,m = 1,2,\ldots,H$, which represent alternative discrete levels of the demand curve in the current year and for next year, respectively. The probability of each demand level's occurring next year is represented by $Pr(D_{m,t+1})$. The value of consumption in the current year depends on both total supply minus carryover, $S_{i,t}-C_{k,t}$, and on the level of the current year's demand curve, $D_{h,t}$, which is known after harvest. The total expected value of consumption for next year depends on the carryover level and the probabilities associated with next year's supply levels and demand curve levels. The carryover decision influences the level of supply next year, but does not influence the level of the demand curve next year.

The dynamic programming procedure for finding the optimal carryovers is slightly changed. With a stochastic demand component included, the optimal carryover must be found for each combination of current year demand and supply levels. The computations for calculating the expected future value of consumption involve an additional summation. For each level of total supply next year, we must first find the expected value of future consumption over all levels of demand next year.

If 40 levels of supply and 40 levels of demand are used in the value of consumption algorithm, then optimal carryovers must be found each year for all 1,600 combinations of supply and demand. This tremendous increase in computational requirements caused by making the optimal grain storage problem more comprehensive is an example of the "curse of dimensionality" in dynamic programming. However, a different formulation of a dynamic programming problem often results in substantial computational savings.

The algorithm shown in equations (7) and (8) has an interesting result that can be used to reduce the number of computations; namely, the level of supply minus the level of demand determines price and carryover. If i to i + 1 and h to h + 1 represent equal increases in the current year's levels of supply and of the demand curve, (for example, 10 million bushels), then price and carryover are not affected. The difference between the supply and demand curves is not changed by these equal increases. However, consumption is increased by an amount equal to the increase in supply (or demand).

This result is useful because it implies that one can achieve computational savings by using the price method to solve for optimal carryovers, that is, by using the first-order conditions. One can achieve these computational savings by using differences between the levels of supply and demand in conjunction with the first-order conditions for maximizing profits from storage.

Let us now return to the problem with 40 levels of each supply and demand. If the increments between the successive levels of supply and demand are equal, then there are still 1,600 combinations of supply and demand levels but only 79 different values for supply level minus demand level. This means that only 79, rather than 1,600, optimal carryover levels need be calculated for each year. The probability of occurrence of each of the differences in supply and demand levels can easily be calculated from the probabilities in equation (8). The probability of a particular difference occurring equals the summation of $[\Pr(S_{j,t+1})$ times $\Pr(D_{m,t+1})]$ over the number of ways that the difference can occur.

When we use the first-order condition given in the previous section, the dynamic programming algorithm performs equally well in solving for optimal carryovers using differences in the levels of supply and demand. Now the current year's price is calculated by use of the supply level minus the demand level and the chosen level of carryover. Also, next year's expected price is calculated by use of the probability of the various supply levels minus demand levels occurring in the following year, given the carryover decision.

For this problem, the i index in equation (5) represents the alternative supply minus demand levels. The probability distribution in equation (5) for this problem represents the probabilities of the alternative supply minus demand levels occurring in the following year, given the carryover decision. An increase in carryover increases the current year's price. It also increases the expected level of total supply next year, thereby increasing the probabilities of large levels of supply minus demand. This situation, of course, reduces the expected price next year.

Gardner (*3*, p. 133) included a random demand component in his study by using the price method rather than the value of consumption method. Gustafson (*5*, p. 51) originally showed how to include a random demand component along with random production.

Optimal Grain Storage When a Rational Production Component is Included

Gardner and Ippolito independently developed dynamic programming algorithms for including rational producer response with optimal grain storage. Gardner's algorithm emphasizes the optimal carryover decision after harvest, assuming the rational production response next year. Ippolito's algorithm emphasizes the rational production decision at planting, given optimal carryovers for each possible level of total supply after harvest. Both algorithms represent major advances in using dynamic programming to analyze grain storage.

A major difference between the two algorithms is in the way that the rational production response is found. Ippolito's algorithm uses an iterative procedure that converges to the rational production response. Gardner's algorithm uses a trial-and-error search procedure which is the typical approach in dynamic programming algorithms. Ippolito's iterative approach diminishes the curse of dimensionality problem that is encountered when a second decision variable is introduced.

Gardner's Algorithm

Gardiner's algorithm uses equations (9) and (10):

$$f_{i,T} = \max_{k=1}[R_{i,T} - C_{k,T}] \quad i = 1,2, \ldots, I \tag{9}$$

$$f_{i,t} = \max_{k} \Big\{ [R_{i,t} \mid S_{i,t} - C_{k,t}] - SC(C_{k,t}) +$$

$$r \sum_{j=1}^{I} [\Pr(S_{j,t+1} \mid C_{k,t}; E(PROD_g))] f_{j,t+1} - rVC_g \Big\}$$

$$k = 1,2, \ldots, K$$
$$g = 1,2, \ldots, G$$
$$i = 1,2, \ldots, I \qquad (10)$$

The indexes t, i, j, and k are the same as defined in equations (1) and (2).

In addition to these indexes, equation (10) contains the index $g = 1,2,\ldots,G$, which represents the possible levels of production next year. The variable $E(PROD_g)$ in equation (10) represents next year's expected production.[6] This equation includes an additional term representing variable production cost, VC_g, which, like storage cost, is subtracted. Including variable production cost means that the value of consumption minus variable production cost is the objective function. This means that the objective of maximizing economic surplus replaces the objective of maximizing the value of consumption.

The computations for this algorithm include straightforward additions to those previously explained for random production and stable demand (equations (1) and (2)). However, there is a subtle difference in the optimal storage behavior. This difference will be discussed later.

The additional computations involve the probability distribution of production outcomes. The rational production decision determines the mean level of next year's possible production outcomes. This is reflected in the probability term in equation (10). With rational production included, there are two decision variables. Both the carryover and production decisions influence next year's total supply. Also, each decision influences the other. That is, carryover and expected production are interdependent endogenous variables; consequently, their levels must be made consistent. In this algorithm, optimal carryovers are found by a two-dimensional search among the carryover and production levels.

[6]The random production specification can be considered as a special case with only one level of production response, g.

The objective of the search is to find the combination that maximizes equation (10).

This algorithm, like that for random production, is started in year T, the last year considered. Additional years are considered until carryover converges to a particular level for each level of total supply and until the rational production level for next year converges to a particular level for each level of carryover from the current year.

An examination of the first-order conditions for maximizing equation (10) reveals the economic behavior involved. Expression (11) and equation (12) show the first-order conditions for storers and producers, respectively:

$$\frac{\partial f_{i,t}}{\partial C_{k,t}} = -P_{i,t} - MSC$$

$$+ rE(P_{t+1} \mid C_{k,t}; E(PROD_{g,t+1})) < 0 \qquad (11)$$

$$P_{i,t} \geq rE(P_{t+1} \mid C_{k,t}; E(PROD_{g,t+1})) - MSC \qquad (11.1)$$

$$\frac{\partial f_{i,t}}{\partial PROD_{g,t+1}} = rE(P_{t+1} \mid C_{k,t}; E(PROD_{g,t+1}))$$

$$- r \frac{\partial VC_g}{\partial PROD_{g,t+1}} = 0 \qquad (12)$$

$$E(P_{t+1} \mid C_{k,t}; E(PROD_{g,t+1})) = MC \qquad (12.1)$$

where VC is the variable production cost and MC is the marginal cost of production.

In this situation, both first-order conditions must be simultaneously fulfilled. The first-order condition for maximizing profits from storage includes the effect of storage on next year's expected production. The first-order condition for maximizing profits from production includes the effect of carryover on production.

The partial derivative with respect to carryover for the first three terms in equation (10) is iden-

tical to those in equation (2) with random production. The partial derivative of the last term in equation (10) with respect to carryover is zero as production is held constant when this partial is taken. The partial derivatives of the first two terms in equation (10) with respect to production next year are both zero. Carryover is assumed to be held constant when these partials are taken. Therefore, neither current year's consumption nor cost of storage is affected. The partial derivatives of the last two terms in equation (10) with respect to production are next year's expected price and the marginal cost of production. The first-order condition in equation (12) shows that producers maximize expected profits by equating expected marginal returns (price) with marginal costs. Notice that the derivatives of the third term, with respect to both carryover and next year's production, are identical. Identical changes in carryover and expected production will change total supply next year by identical amounts and, hence, the expected value of consumption next year by identical amounts.

For each level of carryover, storers know the expected production response. It is the expected production level, given carryover, that equates expected producer price and marginal production cost in the following year. Thus, carryover and next year's expected production come in "ordered" pairs. Storers choose that pair which also fulfills the first-order condition in expression (11). As under random production, this choice maximizes their expected profits from storage.

A random demand component can be included with optimal storage and rational production just as with optimal storage and random production. As under random production, computational savings are gained by the addition of the random demand component to the first-order conditions (expression (11) and equation (12)) rather than to the value of consumption equations (equations (9) and (10)).

Ippolito's Algorithm

Gardner's algorithm solves for the current year's carryover and next year's expected production. Ippolito's algorithm solves for the current year's expected production and the current year's carryover. Because carryover and production decisions follow one another ad infinitum, the choice of which half of the cycle to put first is arbitrary.

Ippolito's algorithm finds the rational production level for each level of carryin in the current year, and it finds the optimal carryover level, given the level of carryin, for each possible combination of production outcomes and demand levels in the current year. As in Gardner's algorithm, the production and carryover decisions are interdependent.

The current year's production and demand in Ippolito's algorithm are specified as $PROD_t = \gamma + \delta E(P_t) + V_t$ and as $Q^D{}_t = \alpha - \beta P_t + U_t$, respectively. The stochastic variables V_t and U_t determine the levels of the current year's supply and demand curves. They are known after harvest. Producer's expected price, $E(P_t)$, is determined at planting. At equilibrium, this is the rational price that equates total expected supply (the given carryin level plus expected production) with total expected demand (expected carryover plus expected current year demand). The current year's price, P_t, is determined after harvest by the carryover decision. The optimal carryover level equates this price with next year's discounted expected price minus the marginal storage cost.

The flow chart in the figure shows the steps in finding carryover and expected production in the current year given a particular level of carryin. Following is a detailed explanation of the flow chart and of the other steps in Ippolito's algorithm. The i index ($i = 1,2,\ldots,I$) indicates the alternative levels of the difference between the levels of the supply curve and the demand curve. The indexes for k and n ($k,n = 1,2,\ldots,K$) indicate the alternative levels of carryover for the current year and carryin from the previous year. As in the previous algorithms, the t index ($t = T, T\text{-}1, T\text{-}2,\ldots$) indicates the year, starting with the most distant year considered.

Equation (13) in the figure shows that the current year's carryover, $C_{k,t}$, is found given the level of carryin, $C_{n,t-1}$, and given the level of the supply curve minus the level of the demand curve, $W_{i,t}$. The stochastic variable $W_{i,t}$ equals V_t minus U_t. Each $W_{i,t}$ represents the probability associated with an interval on the probability distribution

Figure

Steps in Ippolito's Algorithm for Determining Carryover and Expected Production

Enter

$$C_{n,t-1} + EPROD + W_{i,t} = C_{k,t} + \alpha - \beta P_{i,t} \qquad i = 1, 2, \ldots, I \tag{13}$$

where $P_{i,t}$ & $C_{k,t}$ are found in (14)

$$(P_{i,t} \mid C_{n,t-1} + EPROD_t + W_{i,t} - C_{k,t}) \geqslant E(P_{t+1} \mid C_{k,t}\,;\, EPROD_{t+1}) - MSC \tag{14}$$

$$E(P_t \mid C_{n,t-1}) = \sum_{i=1}^{I} [Pr(W_{i,t})]\, P_{i,t} \tag{15a}$$

$$E(PROD_t) = \gamma + \delta E(P_t \mid C_{n,t-1}) \tag{15b}$$

$$E(D_t) = \alpha - \beta E(P_t \mid C_{n,t-1}) \tag{15c}$$

$$E(C_t) = \sum_{i=1}^{I} [Pr(W_{i,t})]\,[C_{k,t} \mid W_{i,t}] \tag{15d}$$

$$ES_t = C_{n,t-1} + EPROD_t - EC_t - ED_t \tag{16}$$

$$|ES_t| < \epsilon \tag{17}$$

Yes → Exit

No

$$X = C_{n,t-1} + EPROD_t \tag{18a}$$

$$Y = X - (\partial ES_t / \partial X)^{-1}(ES_t) \tag{18b}$$

$$EPROD_t = Y - C_{n,t-1} \tag{18c}$$

of W_t. The intervals for all the $W_{i,t}$'s define the probability distribution of W_t in discrete segments.[7] As previously explained, the supply curve level minus the demand curve level (in this algorithm, $W_{i,t}$) is a determinant of carryover and price. An assumed value of expected production, $EPROD_t$, is first used in equation (13) for a given level of carryin. Improved estimates of expected production are calculated from the results of equation (13) for all the values of $W_{i,t}$ given a particular level of carryin. The procedure for calculating improved estimates of expected production is explained later.

Equation (13) is solved for carryin for all values of $W_{i,t}$ given a particular level of carryin, $C_{n,t-1}$, by use of expression (14). This expression differs from Gardner's expression (11.1) only in that specific alternative production levels are not specified prior to using the algorithm. A trial-and-error search is made among the possible carryover levels, $C_{k,t}$, given the level of $C_{n,t-1} + EPROD_t + W_{i,t}$, to find the level that makes the current year's price in (14) equivalent to next year's discounted expected price minus the marginal storage cost. This trial-and-error search is done for each value of $W_{i,t}$. One calculates the current year's price, $P_{i,t}$, from the demand equation, $Q = \alpha - \beta P_t$, by using $C_{n,t-1} + E(PROD_t) + W_{i,t} - C_{k,t}$ as the value of Q.

To start the algorithm, assume next year's carryover, year T, equals zero regardless of the carryover level from the current year, year T-1. This restriction allows us to find next year's expected price by setting carryin plus the supply equation equal to the demand equation and then by solving for expected price, $E(P_T \mid C_{k,T-1}) = (-C_{k,T-1} + \alpha - \gamma)/(\beta + \delta)$. The expected price is found for each level of carryover, $C_{k,T-1}$, from the current year (carryin for next year). Next year's expected production equals $E(PROD_T) = \gamma + \delta\ E(P_T \mid C_{k,T-1})$. Next year's expected price for each level of carryover from the current year, $E(P_T \mid C_{k,T-1})$, is the information we need to determine the optimal carryover level using expression (14).

The results from equation (13) for a given level of carryin are used to determine whether the value of expected production used in this equation is within an allowable limit of equating total expected supply with total expected demand. First, as shown in (15a), the expected price, $E(P_t \mid C_{n,t-1})$, is calculated from the results of equation (13). Next, the expected production, $E(PROD_t)$, and the expected current year demand, $E(D_t)$, implied by this expected price, are calculated in (15b) and (15c). Finally in (15d), the expected carryover, $E(C_t)$, is calculated from the results of equation (13). These expected production, $E(PROD_t)$, and the expected in, are used in equation (16) to determine the expected excess supply.

This is the excess supply that rational producers would expect given the sum of carryin and the tentative value of expected production used in equation (13). Next, expression (17) determines if the absolute value of this expected excess supply is less than a small positive value, ϵ. If not, we calculate an improved, but still tentative, estimate of expected production using (18a), (18b), and (18c). This improved estimate is then used in equation (13).

Ippolito showed that the expected excess supply decreases monotonically as total expected supply increases. This decrease implies that there is a unique value of total expected supply which has a zero excess supply. Ippolito also showed that the derivative of expected excess supply with respect to total expected supply lies between $-(\beta+\delta)/\beta$ and -1.[8] One finds an improved estimate of total expected supply by approximating the excess supply function by its linear tangent at the current estimate of total expected supply. The improved estimate of total expected supply is calculated in equation (18b); it is the value that makes the linear approximation equal to zero. Because carryin is given or fixed, the improved estimate of expected production equals the improved estimate of total expected supply minus

[7] It is convenient to make $W_{i,t}$ the midpoint of interval i and to make all the intervals of equal width.

[8] The derivative of the expected excess supply function with respect to total expected excess supply equals $\frac{\alpha}{\beta}\left(\frac{\beta + \alpha}{\beta(r+1) + \alpha} PROB - 1\right) - 1$. The variable PROB is the probability that carryover for the current year is greater than zero and equals $\sum_{i=1}^{Z} Wi,t$ (where Wz,t represents the smallest value of Wi,t resulting in carryover greater than zero in year t). The values of Wi,t in this summation decline in succession from the largest value to the smallest value associated with carryover greater than zero. PROB increased with increasing sums of carryin and expected production.

carryin as shown in equation (18c). The improved estimate of expected production is then used in equation (13).

Ippolito's algorithm proceeds by using improved estimates of expected production in equation (13) to calculate optimal carryover levels and by using the results of equation (13) to calculate improved estimates of expected production. This iterative procedure is continued until the absolute value of the expected excess supply in expression (17) is less than the small positive value, ϵ. At this point, the optimal carryover decision and the rational production decision are consistent for the given level of carryin. Using this procedure, one calculates the rational production decision and the optimal carryover decision for each level of carryin in the current year.

The current year's results from the algorithm include the current year's expected price for each level of carryin. From the viewpoint of the previous year, next year's expected price is known for each level of carryover. This information is used to solve equation (13) and expression (14) for carryover in the previous year. Also, one finds improved estimates of expected production by iterating the results of equation (13) for a given level of carryin until the expected production is the rational production level—that is, until the absolute value of excess supply is less than the small positive value, ϵ.

Additional years are considered until the optimal carryover converges to a particular value for each sum of carryin, expected production, and supply level minus demand level ($C_{n,t-1} + E(PROD_t) + W_{i,t}$) and until the rational production level converges to a particular level for each level of carryin. At this point the influence of the zero carryover restriction in the last year, year T, has been completely dissipated.

For an example of the use of Ippolito's algorithm, readers may check our paper (*4*). We used the algorithm to find optimal storage rules and rational production responses for the U.S. soybean market. The efficiency of Ippolito's algorithm enabled us to find optimal storage rules and production responses under the additional constraint of a price band supported by buffer stocks. We also performed stochastic simulations of several price-buffering grain storage policies, and we analyzed the resulting distributions of prices and production.

Conclusions

The two dynamic programming algorithms involving rational producer response that Gardner and Ippolito developed are the most advanced in the optimal grain storage literature. Both are logical extensions of Gustafson's original dynamic programming algorithms which are the foundation for this literature. When these algorithms are described with the same notation, the close relationships among them become clear.

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The Food and Agricultural Policy Simulator: The Poultry- and Egg-Sector Submodel

Larry E. Salathe, J. Michael Price, and Kenneth E. Gadson*

Abstract

The poultry- and egg-sector submodel of USDA's Food and Agricultural Policy Simulator (FAPSIM) endogenously estimates supply, production, ending stocks, retail and wholesale prices, civilian consumption of chicken, turkey, and eggs, the number of layers on farms, the consumer price index for poultry, and cash receipts from marketing of poultry and eggs. This article presents the model's structure, parameter estimates, and validation statistics. The model predicts that a 200-million-pound increase in broiler meat exports would increase broiler prices by about 2 cents per pound.

Keywords

Chickens, econometric model, eggs, simulation, turkeys

Introduction

A variety of econometric models examine the economic forces affecting the poultry and egg sector (*1, 3, 4*).[1] Such models recognize interrelationships between the poultry and egg sector and the beef, pork, and feed-grain sectors, but generally treat these other sectors as exogenous. The failure to endogenize beef, pork, and feed grains could lead to substantial errors when the effects on the poultry and egg sector of alternative future policies are forecast. For example, because poultry is a substitute for red meat, higher poultry prices increase red meat consumption and raise red meat prices. Higher red meat prices, in turn, lead to even higher poultry prices. Thus, if the beef and pork sectors are assumed to be exogenous, a model will underestimate changes in poultry prices.

Recent production, consumption, and price movements indicate a strong interrelationship between poultry and red meat. U.S. per capita consumption of chicken increased from 14.1 pounds per year in 1940 to 27.8 pounds in 1960 and 50.0 pounds in 1980 (*10, 11*). Lower retail prices for chicken relative to red meat probably contributed significantly to the expansion in chicken consumption. Between 1960 and 1980, the retail price of chicken rose 80 percent, while the retail prices of beef and pork rose 193 and 156 percent, respectively. During the same period, per capita consumption of chicken rose by 80 percent, compared with a 12-percent increase in per capita beef consumption and a 13-percent increase in per capital pork consumption. Future growth in per capital consumption or the price of chicken may be slowed significantly if beef and pork supplies are large enough to limit future price increases in red meat.

This article presents the poultry- (chicken and turkey) and egg-sector submodel contained in the U.S. Department of Agriculture's (USDA's) Food and Agricultural Policy Simulator (FAPSIM).[2] We present the poultry and egg submodel's structure, parameter estimates, historical performance, and linkages to other commodity sectors. In addition, we use the model to explore the impacts of

*The authors are agricultural economists with the National Economics Division, ERS.

[1] Italicized numbers in parentheses refer to items in References listed at the end of this article.

[2] FAPSIM is an annual econometric model of the agricultural sector. It contains models for beef, pork, dairy, poultry and eggs, corn, grain sorghum, oats, barley, wheat, cotton, and soybeans, which are linked via common variables. The model estimates a price-quantity equilibrium solution that is consistent across all commodities. For more information, see (*7*).

changes in broiler exports on U.S. agriculture and examine the errors generated by failing to allow for feedback from the beef, pork, and feed-grain sectors.

Structure of the Poultry- and Egg-Sector Submodel

The submodel explicitly recognizes the linkages between chickens and eggs at the producer level and between chickens and turkeys at the retail level. The dual role of chickens and eggs as both food products and as necessary inputs required for egg and chicken production requires that numerous linkages be constructed at both the producer and retail levels. Table 1 contains the definitions of the variables included in the submodel, and tables 2, 3, 4, and 5 contain the equations which describe the linkages between these variables.

Supply

The structure of the poultry and egg sector changed dramatically during recent decades. The trend was toward larger farms and more mechanized production. Mechanization plus improvements in disease control and feed conversion helped boost production efficiency. Over the past 25 years, output per hour of labor for all poultry and egg production increased nearly sevenfold. Poultry and egg producers maintained and sometimes expanded production even during periods of low prices.

Poultry and egg producers can adjust output during the year by changing the number of chicks or poults started, by changing the frequency of batches raised, by adjusting market weights, or by culling or recycling layers. Year-to-year production response is limited, however, by a variety of economic and biological factors. First, the availability of chicks and poults from breeding flocks can constrain production response. Second, expansion in housing capacity may be limited due to the high investment costs associated with poultry and egg production. Depending on the type of housing, equipment, unit size, and climate, investment costs per bird may be $4-$10 per layer, $2-$4 per broiler, and $3-$8 per turkey (*8*). Third, considerable poultry and egg production is under contract to market firms or is carried out as only one phase within vertically integrated firms. High investment costs and the extensive network of linkages between production units and input-supplying and marketing functions limit the extent to which poultry and egg producers respond to year-to-year fluctuations in economic variables.

The production cycle for broilers and turkeys is short, and producers can alter production within a year in response to current economic signals. However, as noted earlier, various biological and economic forces tend to constrain the level of year-to-year change. Given these constraints, we express young chicken (CHISPYO) and turkey (TURAP) production as functions of their respective (current and lagged) wholesale price deflated by the cost of feed, lagged production, and time—a proxy for technological change (table 2).[3] Total chicken production consists of slaughter of young (broilers) and other chickens (hens, surplus cockerels, and fowl from egg-producing flocks). Production of other chickens largely reflects producers' decisions to reduce or expand egg production. If producers reduce the size of the layer flock in response to lower egg prices, there will be fewer hens, reducing other chicken production. Therefore, we express production (slaughter) of other chicken (CHIAPOT) as a function of the number of layers on farms. The number of layers (CHISVLA) is, in turn, a function of the lagged number of layers on farms and the ratio of egg prices to feeding costs. Total supplies of chicken (CHIASYO), turkey (TURAS), and other chicken (CHIASOT) depend on production plus beginning stocks.

We determine total egg production (EGGAP) by multiplying the number of layers and egg produc-

[3] A number of alternative equation specifications were estimated to test the relationship between poultry and egg production and current and lagged poultry and egg prices and feeding costs. Equations specifying production as a function of the sum of current and lagged ratios of price-to-feeding costs were selected for inclusion in the model because these equations generally possessed lower mean square errors and other desirable properties, such as more significant coefficients with appropriate signs than alternative specifications.

We estimated the parameters of the poultry and egg submodel by using ordinary least squares. Annual data for three time periods (1950-79, 1955-79, 1960-79) were selected for estimation. The set of equations selected for the model represents the best set based on hypothesized parameter signs, significance of parameters, and the standard error of regression.

Table 1—Variable definitions for poultry and egg submodel

Variable	Definition
Endogenous:	
CHISPYO	Production of young chicken, million pounds
CHIASYO	Supply of young chicken, million pounds
CHIHTYO1	Ending stocks of young chicken, million pounds
CHICCYO	Civilian disappearance of young chicken, million pounds
CHIAPOT	Production of other chicken, million pounds
CHIASOT	Supply of other chicken, million pounds
CHIHTOT1	Ending stocks of other chicken, million pounds
CHICCOT	Civilian disappearance of other chicken, million pounds
CHIIRFR	Retail price index of frying chicken, 1967 = 1.0
CHIPR	Retail price of chicken, cents per pound
CHIPWBR9C	Wholesale price of broilers, nine-city, cents per pound
CHIPWXB	Wholesale price of nonbroilers, cents per pound
CHISVLA	Number of layers on farms, million head
EGGAA	Egg production per layer
EGGBB	Eggs used for hatching, million dozen
EGGAP	Production of eggs, million dozen
EGGAS	Supply of eggs, million dozen
EGGCC	Civilian disappearance of eggs, million dozen
EGGHT	Ending stocks of eggs, million dozen
EGGIR.67	Consumer price index of eggs, 1967 = 1.0
EGGPRAL	Retail price of eggs, large grade A, cents per dozen
EGGPF	Average price received by farmers for eggs, cents per dozen
TURAP	Production of turkey, million pounds
TURAS	Supply of turkey, million pounds
TURHT1	Ending stocks of turkey, million pounds
TURCC	Civilian disappearance of turkey, million pounds
TURPR	Retail price of turkey, cents per pound
TURPF	Average price received by farmers for turkey, cents per pound
.PCPOU	Consumer price index for poultry, 1967 = 1.0
POUFC	Cash receipts from marketings of poultry and eggs, million dollars
Exogenous:	
CORPF*	Average price received by farmers for corn, October-September, dollars per bushel
SORPF*	Average price received by farmers for grain sorghum, October-September, dollars per bushel
BARPF*	Average price received by farmers for barley, June-May, dollars per bushel
OATPF*	Average price received by farmers for oats, June-May, dollars per bushel
WHEPF*	Average price received by farmers for wheat, June-May, dollars per bushel
SOMPF*	Price of soybean meal, Decatur, dollars per hundredweight
PORIR.67*	Consumer price index for pork, 1967 = 1.0
BEEIR*	Consumer price index for beef and veal, 1967 = 1.0
.PC*	Consumer price index for all items, 1967 = 100
.YPD$	U.S. personal disposable income, billion dollars
.NPC	Total U.S. population, millions
.WRHPP	Poultry processing industry wage rate, dollars per hour
.GASIR	Consumer price index for regular and premium gasoline, 1967 = 1.0
DUMij	Dummy variable, 19ij
DUMijkl	Dummy variable, 19ij - 19kl
CHICMYO	Military consumption of young chicken, million pounds
CHIMXYO	Exports of young chicken, million pounds
CHICMOT	Military consumption of other chicken, million pounds
CHIMXOT	Exports of other chicken, million pounds
EGGCM	Military consumption of eggs, million dozen
EGGMI	Imports of eggs, million dozen
EGGMX	Exports of eggs, million dozen
FDC	Feed cost index, chickens
FDE	Feed cost index, eggs
FDT	Feed cost index, turkeys
TURCM	Military consumption of turkey, million pounds
TURMX	Exports of turkey, million pounds
.TIME	Time trend 1950 = 50, 1951 = 51, and so forth

Note: Asterisk (*) denotes variables that are exogenous to the poultry- and egg-sector submodel, but are endogenously predicted by other FAPSIM submodels.

Table 2—Supply relationships

Variable	Equation
CHISPYO	– 13852.6 + 211.806 .TIME + 0.570838 CHISPYO(–1) + 94.6545 (CHIPWBR9C(–1)/FDC(–1) + CHIPWBR9C/FDC) (–3.33) (3.17) (3.22) (2.91)
	R^2 = 0.982
CHIASYO	CHISPYO + CHIHTYO1(–1)
CHIAPOT	74.6666 + 2.26567 CHISVLA (0.47) (4.25)
	R^2 = 0.532
CHIASOT	CHIAPOT + CHIHTOT1(–1)
TURAP	– 2594.40 + 0.210301 TURAP(–1) + 49.6344 .TIME + 24.2195 (TURPF(–1)/FDT(–1) + TURPF/FDT) (–3.43) (0.88) (4.13) (1.97)
	R^2 = 0.876
TURAS	TURAP + TURHT1(–1)
CHISVLA	93.9849 + 13.0996 DUM67 + 0.588864 (EGGPF(–1)/FDE(–1) + EGGPF/FDE) + 0.604911 CHISVLA(–1) (3.46) (2.84) (2.83) (5.58)
	R^2 = 0.881
EGGAA	51.2774 + 0.552840 EGGAA(–1) + 0.709783 .TIME (1.86) (2.43) (2.05)
	R^2 = 0.954
EGGAP	(CHISVLA)(EGGAA)/12.0
EGGAS	EGGAP + EGGHT(–1) + EGGMI

Note: Numbers in parentheses are Student-t values.

tion per layer. Egg production per layer has been steadily increasing, paralleling improvements in disease control and layer quality. We do not attempt to predict improvements in disease control and layer quality over time and express egg production per layer (EGGAA) simply as a function of lagged egg production per layer and a time trend. The total supply of eggs (EGGAS) equals the sum of egg production, beginning stocks, and imports. Imports are treated as exogenous.

The feed cost variables (FDE, FDC, FDT) are weighted sums of the prices of corn, oats, grain sorghum, wheat, barley, and soybean meal (table 3). The weights reflect the average relative importance of wheat, soybean meal, and feed grains in broiler and layer rations. Since crop prices are exogenous to the poultry- and egg-sector submodel, the feed cost variables are also. These feed cost variables link the poultry and egg submodel with the wheat, soybean, and individual feed-grain submodels contained in FAPSIM.

Consumption and Stocks

We calculate civilian consumption of chicken (young and other) (CHICCYO) and turkey (TURCC) by subtracting exports, ending stocks, and military consumption from total supply (table 4). Military consumption and exports are treated as exogenous. A similar identity, which adjusts downward the available supply of eggs by the number of eggs used for hatching, is used to estimate civilian consumption of eggs (EGGCC). The quantity of eggs used for hatching (EGGBB) is directly related to the number of layers on farms and young chicken production. An expansion in young chicken production is associated with an increase in eggs used for hatching and a reduction in the quantity of eggs available for consumption.

Table 3—Exogenous feed cost indexes

Variable	Equation
FDE	0.4838 CORPF(-1) + 0.0852 SORPF(-1) + 0.0227 WHEPF(-1) + 0.2500 SOMPF(-1) + 0.1263 OATPF(-1) + 0.0320 BARPF(-1)
FDC	0.6081 CORPF(-1) + 0.0513 SORPF(-1) + 0.0173 OATPF(-1) + 0.0044 BARPF(-1) + 0.0031 WHEPF(-1) + 0.3157 SOMPF(-1)
FDT	0.5091 CORPF(-1) + 0.1341 SORPF(-1) + 0.0471 OATPF(-1) + 0.0119 BARPF(-1) + 0.0085 WHEPF(-1) + 0.2893 SOMPF(-1)

Table 4—Consumption and stock relationships

Variable	Equation
CHICCYO	CHIASYO - CHIHTYO1 - CHICMYO - CHIMXYO
CHIHTYO1	62.7349 + 19.9557 DUM6667 - 26.9081 CHIIRFR/CHIIRFR(-1)
	(3.62) (3.27) (-1.62)
	R^2 = 0.417
CHICCOT	CHIASOT - CHIHTOT1 - CHIMXOT - CHICMOT
CHIHTOT1	93.5894 + 0.0354460 CHIAPOT - 20.1003 CHIIRFR/CHIIRFR(-1) - 28.7933 DUM6869
	(10.92) (0.37) (-0.54) (-2.25)
	R^2 = 0.143
TURCC	TURAS - TURHT1 - TURCM - TURMX
TURHT1	341.184 + 0.225232 TURHT1(-1) + 127.497 DUM67 + 115.976 DUM73 - 167.787 TURPR/TURPR(-1)
	(2.72) (1.38) (3.32) (2.24) (-1.46)
	R^2 = 0.490
EGGCC	EGGAS - EGGHT - EGGBB - EGGCM - EGGMX
EGGHT	- 28.7092 + 0.693292 EGGHT(-1) + 0.0184625 EGGAS - 61.3829 EGGIR.67/EGGIR.67(-1)
	(-0.38) (3.81) (1.44) (-3.42)
	R^2 = 0.515
EGGBB	435.293 - 8.74153 .TIME + 0.374997 CHISVLA + 0.0596407 CHISPYO
	(2.64) (-3.51) (1.73) (7.62)
	R^2 = 0.978

Note: Numbers in parentheses are Student-t values.

The demand for stock holdings consists of two components: (1) speculative and (2) transactions (*6*). The speculative component refers to the holding of stocks as a means of benefiting from price fluctuations. The transactions component refers to stocks used to conduct day-to-day business operations.

The transactions component is normally expressed as a function of sales, whereas the speculative component is normally expressed as a function of expected price. Therefore, we express commercial stock levels as a function of total supply and the ratio of current to lagged retail price. The regression results suggest that commercial stocks of young chicken (CHIHTYO1), other chicken (CHIHTOT1), and turkey (TURHT1) are not greatly influenced by beginning stock levels, production, or retail prices (table 4). However, ending stocks of eggs (EGGHT) were significantly

related to both the level of beginning stocks and the retail price of eggs.

Prices

We estimated equilibrium retail prices of chicken (CHIPR), turkey (TURPR), and eggs (EGGPRAL) by inverting retail demand equations which express consumption of each commodity as a function of per capita disposable income, own real retail price, and the real retail prices of substitute commodities. We hypothesize that turkey and chicken are competing products at the retail level and that both compete with beef, pork, and fish for the consumer's food dollar.

The regression results indicate that the real retail prices of frying chicken and turkey are positively related (table 5). Increases in the retail prices of pork and beef also positively influence the retail prices of chicken (CHIIRFR) and turkey (TURPR). But, the retail prices of turkey and chicken were not significantly related to the retail price of fish. For this reason, the retail price of fish was not included in the equations for these variables. The retail price of eggs (EGGIR.67) is not significantly affected by changes in the retail prices of other foods or in per capita disposable income. We include a time trend in the retail egg price equation to account for the effects of increased consumer awareness of cholestrol intake. These retail price equations directly link poultry to the beef and pork submodels contained in FAPSIM.

We express the level of market (farm) prices for (young) chicken (CHIPWBR9C), turkey (TURPF), and eggs (EGGPF) as functions of their corresponding retail price and variables which reflect meat processing and marketing costs. The wage rate in each livestock processing industry and a general fuel price index are assumed to reflect changes in meat processing and marketing costs.

The regression results indicate that changes in marketing costs affect farm prices of chickens (CHIPWBR9C). However, marketing cost variables appear not to significantly affect farm-level egg prices (EGGPF). This merely reflects the limited processing that eggs undergo between the farm gate and the grocery shelf.

We express the wholesale market price of nonbroilers (spent hens) (CHIPWXB) as a function of the market price of broilers and the relative proportion of total chicken consumption accounted for by nonbroilers. Holding all other factors constant, we expect that the increase in other chicken consumption brought about by an increase in other chicken production places downward pressure on the price of nonbroilers (CHIPWXB).

Four auxiliary equations close out the poultry and egg submodel. The first equation links the consumer price index (CPI) for poultry (.PCPOU) to the retail index for frying chicken and the retail price of turkey. The CPI for poultry in turn is used by another sector of FAPSIM to compute the CPIs for food and all items. The second equation predicts farm cash receipts from marketings of poultry and eggs (POUFC). In turn, FAPSIM uses this latter equation to estimate net farm income. The final two equations express the retail prices of chicken (CHIPR) and eggs (EGGPRAL) as functions of their corresponding retail indices.

Validation Procedures

The equations contained in the poultry and egg sector submodel appear to contain parameters of appropriate sign and magnitude. However, such characteristics do not ensure that the entire system of equations will accurately predict events. We use model predictions for historical periods to examine the model's predictive ability.

The most widely used validation statistics include the mean absolute relative error, Theil's U, U_1, and U_2 statistics, and turning point error (*9*). The definitions of these statistics along with a discussion of their properties may be found in (*5*).

The poultry and egg submodel was validated over the 1966-80 period. For each year, the model was solved by use of a Gauss-Seidel solution algorithm (*2*). We used historical values for all nonpoultry- and egg-sector variables contained in FAPSIM, and we allowed the poultry and egg submodel to generate values for all lagged endogenous variables in the poultry and egg submodel. Thus, errors in model predictions over the validation period reflect the model's failure to predict economic events

Table 5—Price relationships

Variable	Equation
CHIIRFR	0.350530 BEEIR + 0.227790 PORIR.67 + 0.00659730 TURPR + 0.00428652 .PC (3.37) (2.50) (2.49) (2.99) - 0.000207805 [(CHICCYO + CHICCOT)(.PC)/.NPC] + 0.160750 .YPD$/.NPC (-4.40) (2.11) - 0.0979468 DUM72 - 0.0869418 DUM74 (-2.91) (-2.43) R^2 = 0.999
CHIPR	2.100 + 36.5252 CHIIRFR (2.87) (62.45) R^2 = 0.995
CHIPWBR9C	- 2.87217 - 1.17604 .WRHPP - 1.45386 .GASIR + 0.834765 CHIPR (-3.96) (-2.57) (-3.21) (28.93) R^2 = 0.995
CHIPWXB	17.7720 - 3.19743 (.TIME-59)**0.5 - 2.89117 DUM75 + 0.326075 CHIPWBR9C (2.32) (-2.83) (-2.40) (6.89) -82.2282 CHICCOT/(CHICCOT + CHICCYO) (-1.91) R^2 = 0.744
TURPR	0.621100 .YPD$/.NPC + 3.0084 PORIR.67 + 17.1236 BEEIR + 22.0145 CHIIRFR (0.25) (0.43) (3.75) (2.37) -0.0383407 [(TURCC)(.PC)/.NPC] - 6.62700 DUM75 - 4.60619 DUM6869 + 0.348050 .PC (-2.91) (-3.30) (-4.02) (3.31) R^2 = 0.999
TURPF	- 7.97843 - 6.4993 DUM74 + 5.27449 DUM78 - 1.09233 .WRHPP - 3.11445 .GASIR + 0.693958 TURPR (-3.05) (-3.43) (2.61) (-0.72) (-1.96) (7.81) R^2 = 0.955
EGGIR.67	0.0614617 .PC - 0.000799868 [(EGGCC)(.PC)/.NPC] + 0.271316 DUM7374 - 0.000449893 (.TIME)(.PC) (6.28) (-3.44) (4.18) (-1.41) R^2 = 0.997
EGGPRAL	2.9118 + 47.0872 EGGIR.67 (3.11) (65.34) R^2 = 0.995
EGGPF	- 9.77410 - 0.259020 .WRHPP - 0.398191 .GASIR + 0.821078 EGGPRAL (-7.85) (-0.39) (-0.55) (26.79) R^2 = 0.999
.PCPOU	0.030092 + 0.896133 CHIIRFR + 0.001477 TURPF (3.85) (41.44) (3.21) R^2 = 0.999
POUFC	- 201.215 + 0.00810359 (CHISPYO)(CHIPWBR9C) + 0.00330590 (CHIAPOT)(CHIPWXB) (-2.14) (9.56) (1.47) + 0.00959384 (EGGAP) (EGGPF) + 0.0227709 (TURAP) (TURPF) - 6.08587 (.TIME-49) (17.13) (7.38) (-1.03) R^2 = 0.999

Note: Numbers in parentheses are Student-t values.

occurring in the poultry and egg sector in any particular year as well as prior ones.

Table 6 presents the validation statistics for the poultry and egg submodel. The equations predict reasonably well over the validation period. The MARE statistics indicate that production of young (CHISPYO) and other chickens (CHIAPOT), eggs (EGGAP), and turkey (TURAP) were predicted within an average error of 4 percent. For all the above variables, Theil's U_2 statistic was below 1.0 and the TPE was below 0.4. Thus, the model performed better than a simple no change from the previous year's forecast model, and the model adequately predicted turning points.

The largest predictive errors occurred for ending stocks of young (CHIHTYO1) and other chickens (CHIHTOT1), eggs (EGGHT), and turkeys (TURHT1). Total stocks of these commodities tend to be small relative to their total demand. Therefore, fairly substantial errors in predicting their levels need not adversely affect the model's overall performance. The MAREs for ending stocks of eggs, young and other chicken, and turkey exceeded 10 percent, but the Theil's U_2 statistics were below 1. Thus, for these variables the model outperformed a no change from the previous year's forecast model.

The retail prices of both chicken (CHIPR) and turkey (TURPR) had MAREs below 4 percent. However, the MARE for the retail price of eggs (EGGPRAL) exceeded 7 percent, even though the total supply of eggs (EGGAS) was generally estimated to within 2 percent. Although the equa-

Table 6—Validation statistics, 1966-80

Variable	Mean absolute relative error	Theil's U statistic	Theil's U_1 statistic	Theil's U_2 statistic	Turning point error[1]
	Percent				
CHISPYO	3.09	0.018	0.302	0.608	0.067
CHIASYO	3.06	.018	.300	.607	.067
CHIHTYO1	24.36	.116	.367	.644	.400
CHICCYO	3.20	.019	.324	.665	.200
CHIAPOT	3.33	.020	.369	.644	.333
CHIASOT	3.37	.021	.364	.612	.267
CHIHTOT1	12.76	.081	.341	.591	.267
CHICCOT	3.96	.023	.369	.607	.467
CHIIRFR	3.50	.021	.210	.396	.400
CHIPR	2.86	.017	.168	.315	.467
CHIPWBR9C	4.77	.027	.225	.415	.467
CHIPWXB	8.36	.054	.265	.437	.267
CHISVLA	1.99	.011	.483	1.022	.267
EGGAA	0.70	.005	.404	.849	.400
EGGBB	3.82	.023	.424	.878	.200
EGGAP	1.77	.011	.474	.864	.200
EGGAS	1.76	.010	.478	.890	.200
EGGCC	1.81	.011	.524	1.045	.267
EGGHT	37.99	.168	.441	.816	.333
EGGIR.67	6.93	.042	.353	.653	.400
EGGPRAL	7.04	.040	.336	.620	.333
EGGPF	9.17	.054	.366	.684	.400
TURAP	3.82	.022	.321	.595	.333
TURAS	3.39	.023	.405	.733	.267
TURHT	12.37	.069	.304	.553	.400
TURCC	3.45	.025	.438	.847	.267
TURPR	3.08	.017	.187	.359	.067
TURPF	7.08	.037	.205	.385	.267
.PCPOU	2.88	.015	.167	.314	.467
POUFC	5.05	.024	.175	.331	.333

[1] The number of turning point errors divided by 15, the total number of possible turning point errors.

tion for the retail price of eggs fit the historical data reasonably well, it missed numerous turning points and significantly underestimated price during the late sixties and early seventies. These changes in the retail price of eggs were not related to the retail prices of other livestock products or disposable income. Many of the errors in predicting the retail price of eggs might be due to using a time trend to control for consumer concerns related to cholesterol intake.

The CPI for poultry (.PCPOU) and cash receipts from farm marketings of poultry and eggs (POUFC) were estimated with little error. The MARE for the poultry CPI was below 3 percent, and the MARE for cash receipts from farm marketings of poultry and eggs was below 6 percent.

An additional validation test is to compare model predictions with actual data for periods not used to estimate the model's equations. Therefore, we performed a 1-year simulation for 1981. Again, the results were encouraging. The only substantial error occurred in the estimate of egg prices. However, the error was below 7 percent.

Analysis of Expansion in Broiler Exports

Between 1975 and 1980, exports of broiler meat increased from 254 million pounds to 722 million pounds. This increase put upward pressure on domestic broiler prices, and, because of the substitution possibilities between chicken, beef, and pork, it also probably put upward pressure on beef and pork prices. Future increases in broiler meat exports are likely because of increased demand for poultry meat by the Middle East, the Far East, the Soviet Union, the Caribbean, and the European Community (*12*).

In the remainder of this article, we utilize FAPSIM's poultry- and egg-sector model and its other livestock and crop models to analyze the impacts of an expansion in broiler exports on the agricultural sector. We evaluated these impacts by comparing FAPSIM model forecasts under two alternative assumptions of broiler meat export levels for 1982-86. The base solution assumed that broiler exports would remain at their 1981 level during the period. The alternative solution assumed that broiler exports would increase by 200 million pounds per year. Thus, broiler meat exports in 1986 were assumed to exceed their 1981 level by 1 billion pounds.

Table 7 presents the changes from the baseline projections resulting from the assumed expansion in broiler meat exports. FAPSIM estimates that the retail price of chicken (CHIPR) would increase 2.3 cents per pound in 1982 if broiler exports expanded 200 million pounds. The retail price of turkey (TURPR) would increase 1.4 cents per pound because of the increase in the price of chicken and the resulting increase in the consumer demand for turkey. Civilian consumption of young chicken (CHICCYO) declines by 164 million pounds whereas young chicken production increases by 34.7 million pounds in 1982. Cash receipts to poultry and egg producers increase by $256.0 million. The adjustments predicted for 1982 seem relatively minor, which is probably reasonable as a 200-million-pound increase in broiler exports represents only about a 2-percent increase in demand for broiler meat.

By 1986, some dramatic adjustments occur in the poultry and egg sector. The expansion in broiler meat exports of 1.0 billion pounds above the baseline pushes the retail prices of chicken (CHIPR) and turkey (TURPR) up by 9.8 and 5.6 cents per pound, respectively. Civilian consumption of young chicken (CHICCYO) falls by 630 million pounds while civilian consumption of turkey (TURCC) increases slightly (26.9 million pounds). Egg production (EGGAP) falls moderately as feed-grain and soybean meal prices increase in response to higher poultry and livestock prices, thereby increasing egg producers' feeding costs. The farm price of eggs (EGGPF) increases by 1.4 cents per dozen, and cash receipts to poultry and egg producers (POUFC) increase by $1.4 billion.

FAPSIM enables one to examine the impacts of the expansion in broiler meat exports on the entire agricultural sector. Such an expansion puts upward pressure on pork and beef prices, which in turn results in adjustments in livestock production and in the demand for feed. There may be sizable effects on the feed-grain, beef, and pork sectors. FAPSIM predicts that the price of slaughter steers will increase by $2.18 per hundredweight and the

Table 7—Impact of increasing broiler meat exports by 200 million pounds per year, 1982-86

Variable[2]	1982	1983	1984	1985	1986
CHISPYO	[1] 34.67	112.66	196.41	281.34	370.29
CHIASYO	34.67	111.79	195.75	280.72	369.64
CHIHTYO1	-.87	-.66	-.62	-.65	-.64
CHICCYO	-164.46	-287.54	-403.64	-518.63	-629.73
CHIAPOT	-.07	-.19	-.31	-.50	-.69
CHIASOT	-.07	-.83	-.79	-.95	-1.18
CHIHTOT1	-.64	-.48	-.45	-.49	-.49
CHICCOT	.58	-.36	-.34	-.46	-.69
CHIIRFR	.06	.11	.16	.21	.27
CHIPR	2.26	3.95	5.75	7.72	9.78
CHIPWBR9C	1.89	3.30	4.80	6.44	8.17
CHIPWXB	.54	.97	1.42	1.93	2.46
CHISVLA	-.03	-.08	-.14	-.22	-.30
EGGAA	.00	.00	.00	.00	.00
EGGBB	2.03	6.82	11.94	16.70	21.83
EGGAP	-.60	-1.68	-2.83	-4.55	-6.32
EGGAS	-.60	-1.80	-3.15	-5.07	-7.04
EGGCC	-2.51	-8.30	-14.56	-21.06	-27.95
EGGHT	-.11	-.32	-.52	-.72	-.92
EGGIR.67	.01	.01	.02	.03	.04
EGGPRAL	.15	.46	.82	1.22	1.68
EGGPF	.13	.38	.67	1.00	1.38
TURAP	4.15	12.18	18.08	22.18	27.00
TURAS	4.15	9.75	15.81	19.97	24.78
TURHT	-2.42	-2.27	-2.20	-2.22	-2.16
TURCC	6.57	12.02	18.01	22.20	26.94
TURPR	1.39	2.32	3.39	4.51	5.61
TURPF	.96	1.61	2.35	3.13	3.89
.PCPOU	.06	.10	.15	.20	.25
POUFC	256.00	500.00	776.00	1075.00	1403.00

[1] Change from baseline projection after increasing broiler meat exports by 200 million pounds per year beginning in 1982.
[2] See table 1 for units of measure.

price of barrows and gilts will increase by $2.78 per hundredweight in 1986. Higher meat prices induce beef and pork producers to expand production. This expansion in pork and beef production coupled with the expansion in young chicken and turkey production increases the demand for feed. By crop year 1985, FAPSIM predicts that the price of corn, wheat, and soybeans will increase by 5.9, 2.3, and 7.1 cents per bushel, respectively. Although cash receipts to poultry and egg producers will increase by $1.4 billion, crop, beef, and pork producers will also benefit from the expansion in broiler exports, causing total farm receipts to increase by $4.1 billion in 1986.

These results suggest that treating and evaluating impacts on the poultry and egg sector without examining the potential feedback effects on other agricultural sectors can lead to misleading statements regarding the total impact on the agricultural sectors. To evaluate the magnitude of error caused by failing to allow for feedback between the poultry and egg sector and other agricultural sectors, we performed an additional simulation. This simulation assumed the same expansion in broiler exports and also assumed that non-poultry- and egg-sector variables would not be affected by the expansion in broiler exports. Table 8 reports the percentage errors in estimates resulting from assuming no feedback between the poultry and egg sector and the beef, pork, and crops sectors.

The results presented in table 8 suggest that treating the poultry and egg sector in isolation may cause sizable errors. FAPSIM predicts that the adjustment in the retail price of chicken due to a 200-million-pound annual increase in broiler meat exports would be underestimated by about 19 percent.

Table 8—Percentage errors in estimates resulting from assuming no feedback between the crops, beef, pork, and poultry and egg sectors, 1982-86

Variable	1982	1983	1984	1985	1986
			Percent		
CHISPYO	[1]-7.02	-5.35	-2.90	0.14	2.31
CHIASYO	-7.02	-5.23	-2.86	.18	2.34
CHIHTYO1	-20.54	-15.47	-19.93	-20.26	-18.33
CHICCYO	1.56	2.12	1.47	-.07	-1.35
CHIAPOT	-132.84	-159.89	-181.09	-186.60	-194.35
CHIASOT	-132.84	-52.29	-82.34	-109.59	-124.83
CHIHTOT1	-21.00	-17.47	-23.83	-26.34	-27.20
CHICCOT	-7.99	-99.10	-160.04	-196.98	-194.47
CHIIRFR	-20.13	-18.27	-19.03	-19.61	-19.72
CHIPR	-20.04	-18.25	-18.94	-19.55	-19.59
CHIPWBR9C	-20.17	-18.34	-18.97	-19.54	-19.61
CHIPWXB	-23.06	-20.87	-21.29	-21.61	-21.47
CHISVLA	-136.67	-162.50	-180.00	-186.82	-196.00
EGGAA	.00	.00	.00	.00	.00
EGGBB	-6.32	-4.64	-2.13	1.06	3.33
EGGAP	-135.05	-160.10	-181.08	-186.86	-194.32
EGGAS	-137.35	-153.48	-168.55	-173.89	-181.69
EGGCC	-34.83	-34.94	-35.92	-38.63	-40.56
EGGHT	-57.89	-55.84	-61.27	-70.53	-78.66
EGGIR.67	-48.55	-42.00	-41.18	-42.31	-44.44
EGGPRAL	-49.26	-42.61	-41.95	-43.44	-44.40
EGGPF	-48.80	-42.44	-41.64	-43.19	-44.30
TURAP	-18.36	-17.92	-15.97	-11.72	-8.93
TURAS	-18.36	-12.92	-12.90	-8.22	-5.83
TURHT	-38.01	-37.36	-43.47	-43.46	-39.46
TURCC	-25.78	-17.54	-16.64	-11.75	-8.53
TURPR	-37.38	-37.45	-39.78	-40.81	-40.59
TURPF	-37.42	-37.47	-39.79	-40.81	-40.55
.PCPOU	-20.69	-19.00	-19.86	-20.41	-21.16
POUFC	-23.44	-21.40	-21.65	-21.86	-21.60

[1] Percentage errors in estimates resulting from assuming the crops, pork, and beef sectors are not affected by the 200-million-pound annual increase in broiler exports during the 1982-86 period.

This underestimate occurs because treating the poultry and egg sector in isolation fails to recognize that an increase in the retail price of chicken puts upward pressure on pork and beef prices. Higher pork and beef prices in turn lead to even higher chicken prices.

The adjustment in egg and turkey prices are also underestimated when no feedback is allowed between the crops, beef, pork, and poultry and egg sectors. Adjustments in both prices are underestimated by about 40 percent. The adjustment in cash receipts from marketings of poultry and eggs is underestimated by about 22 percent.

Conclusions

The poultry and egg industry has radically changed since 1950. Changes include production on fewer and larger farms, expanding output, and integration of production with input-supplying and marketing functions. Poultry and egg production expanded despite declining real prices because of mechanization and improvements in feeding efficiency and disease control.

These structural changes in the poultry and egg industry have important implications for the pork and beef industries. Because consumer demands

for pork and beef are affected by the price of poultry, expansion in poultry production puts downward pressure on red meat prices.

The poultry- and egg-sector model described here explicitly recognizes the complexity of the poultry and egg sector and potential feedback effects on the pork and beef industries. The model has also been integrated into FAPSIM. This makes it possible to estimate impacts of changes in poultry- and egg-sector variables on both crop and livestock producers while allowing for feedback among the different sectors of the model.

We have shown that the failure to allow for feedback among the crops, beef, pork, and poultry and egg sectors results in an underestimate of the price adjustment that would occur as a result of an expansion in broiler meat exports. Because the magnitude of error is sizable, it appears that using a partial equilibrium framework to analyze the poultry and egg sectors may lead to serious prediction errors.

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Research Review

The Regulation of Advertising

John M. Connor*

Use of brand or company names in this article is for identification only and implies neither approval nor disapproval by the U.S. Department of Agriculture. All such examples are drawn from the public record.

Introduction

That buyers and sellers make rational choices with adequate information is one of the sufficient conditions of efficient market performance. In practice, consumers do not have as much access to information about products as do manufacturers. Likewise, consumers typically have less technical expertise than sellers do to evaluate available information and less incentive to acquire information. Even if all economic agents were well informed, private markets would in general produce too little information. This is so because the public-good characteristics of information make it difficult for producers to cover the costs of dissemination of knowledge to those consumers who benefit from it. For all these reasons, markets for consumer products may fail to produce efficient or equitable market solutions (*12*).[1]

Market failure generated by inadequate or misleading information is the principal economic argument for consumer protection legislation(*23*). In the food system, Government intervention intended to correct informational inadequacy takes the form of labeling rules, product standards of identity, inspection of processing plants, and advertising regulation (*14*). The proper role of advertising in the food system has been one of the most controversial issues for quite some time (see *4*, *19*, *28*). Even more rancorous is the debate over the contribution that advertising regulation makes to performance. Nearly half of all U.S. advertising is for grocery products, yet researchers in agricultural economics have contributed relatively little to this debate (*2*).

The last decade saw a significant expansion of public policies directed toward advertising (*1*). But, recent shifts in public sentiment have led to a reevaluation of regulations introduced during the seventies. At the same time, the courts are considering challenges to the legality of restraints on commercial advertising by trade associations. This article surveys the laws, administrative procedures, and voluntary group practices that constrain the content of advertising in the United States. Special attention is given to examples involving food or grocery products. The concluding section offers suggestions for economic research on the regulation of advertising.

Consumer Protection Regulations

Several Federal agencies have authority over various facets of advertising or sales promotion practices in the U.S. food system. The most influential agency is the Federal Trade Commission (FTC) (*1*, *10*). Most States have laws similar to Federal statutes that are enforced by State attorneys general or consumer protection offices (*11*).

The judicial system regulates advertising through its power to enforce contracts under common law and to hear appeals from agency rulings. In legal theory, any buyer may sue a seller under common law provisions if the buyer believes that an advertising claim is fraudulent (*7*). However, misstatements made by food advertisers could never be successfully brought into the courts by individuals because false advertising suits require proof of a significant monetary loss. Sellers may sue other advertisers for disparagement of their products. In both cases plaintiffs must generally prove fraudulent intent or "reckless disregard for the

*The author is an economist with the National Economics Division, ERS. He benefited from criticism by Bruce Marion, Clark Burbee, Robert L. Wills, Ronald Ward, Willard F. Mueller, Jose Costa, and two anonymous reviewers. He is especially grateful for the detailed comments provided by R. Dennis Murphy and Gerald J. Thain.

[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

truth."[2] The U.S. Postal Service monitors and prosecutes mail fraud.

FTC Deceptiveness Enforcement

Section 5 of the 1914 FTC Act goes considerably beyond common law in its potential for placing constraints on advertising (*20*, *29*, *31*). This section declares "unfair or deceptive acts or practices" unlawful without spelling out in detail what is meant by these terms. Over the last 40 years, case law has evolved standards of regulation that have permitted the FTC to issue cease-and-desist orders concerning false, deceptive, or misleading claims.[3] The burden of proof is on the FTC to establish that an advertising claim has the "tendency or capacity to deceive." Though not legally required to do so, the FTC commonly provides evidence, often subpoenaed company surveys, that a "significant minority" of consumers were in fact misled by the advertisement (*1*).[4]

A second method of relief open to the FTC is the consent decree. Consent decrees are agreements between the FTC and a company alleged to have deceived. Without admitting guilt, the company agrees to avoid certain practices in the future. Consent decrees have the advantage of providing a speedy alternative to litigation and of raising the penalities for future violations of the decree. Unlike cease-and-desist orders, they are never reviewed by the courts.

A third form of relief can be sought by the FTC when an advertisement has been found to be deceptive (*22*). In cases where deception is believed to be a widespread industry practice, the FTC has proposed and issued Trade Regulation Rules (TRRs) requiring affirmative disclosure of specific facts. The first instance of this kind of remedy was a trade regulation rule regarding the advertising and labeling of cigarettes. Proceedings regarding the rule began in January 1964, immediately after release of a Surgeon General's report warning of a causal connection between cigarette smoking and lung cancer. The rule, issued in June 1964, required all cigarette ads and packages to carry the message "Cigarette smoking is dangerous to health and may cause death. . ." (*6*).[5] Since 1970, the FTC has issued several more TRRs requiring affirmative disclosure.[6]

Two other proposed rules requiring affirmative disclosure concern television advertising directed at children and food advertising claims in general.[7] The children's advertising inquiry arose because of concerns that children are misled as to the long-term harm that can result from consumption of candy, sugared cereals, and the like (*33*). There are doubts about the ability of children to act as rational consumers with respect to any advertised product. Following a lobbying effort by a coalition of food firms, the broadcasting industry, and associations of advertising agencies that reputedly cost between $15 and $30 million, the Congress in 1981 directed the FTC to cease work on a rule for children's ads (*13*, *16*).

Finally, a fourth form of relief used by the FTC under the deceptiveness doctrine is called "corrective" advertising (*5*). Corrective advertising is used in cases where it is believed that only future advertising messages can correct the residual effects

[2] An individual consumer might be successful in an action where food safety is involved, because this is a question of product liability rather than false advertising. Note that this article does not address the rights of advertisers to "commercial free speech" under the first amendment to the Constitution.

[3] The courts have consistently held that no private actions by consumers or consumer groups may be pursued under the FTC Act. FTC enforcement is exclusive. However, a few States permit private actions under their "little FTC acts." Very few FTC orders have been overturned on appeal to the Federal courts. For a brief overview of regulation abroad, see (*35*).

[4] Examples of ads ruled deceptive by the FTC are: a yogurt advertisement that said "Dannon is known as nature's perfect food that science made better"; a magazine ad that showed soup—thickened with marbles—pouring out of a "chunky" Campbell soup can; and a Profile bread ad that claimed lower calories per slice without disclosing that this was because its slices were much thinner than most breads.

[5] The Cigarette Labelling and Advertising Act of 1965 substituted the current, milder warning for 5 more years. Moreover, the FTC was required to wait until expiration of this law before enacting any other cigarette advertising rules.

[6] Other examples of affirmative disclosure rules in effect include light-bulb durability, octane ratings for gasoline, the "R-value" of home insulation products, and energy-efficiency labeling for home appliances.

[7] Work on a rule on voluntary nutrition claims in advertising began at the FTC in 1974 (*8*). The proposed TRR seeks to define or circumscribe the use of the terms "natural," "nutritious," and others; it would require that energy claims be accompanied by specific calorie ratings and that foods that claimed to help prevent heart disease reveal cholesterol levels. In April 1982, the newly appointed director of the FTC's Bureau of Consumer Protection recommended that the Commission reject the proposed rule (*18*). However, in late 1982 the Commission voted provisionally to approve promulgation of the rule.

of a long history of false advertising. The most famous case involved a Listerine mouthwash advertisement which claimed that because it killed germs it also prevented colds. The FTC required subsequent Listerine ads to tell potential users that it is ineffective in preventing disease. This kind of relief, if it dissuades consumers from purchasing the item, is much more costly to the advertisers than the consent-decree approach.

The only legal defense for an admittedly deceptive advertisement is puffery (*24*). Puffs are advertising claims that are so vague, subjective, or exaggerated that reasonable buyers cannot find them credible or persuasive (for example, "Milwaukee's finest beer"). In addition to qualitative statements, some writers consider deceptive comparative price claims—such as "warehouse prices," "lowest price ever," or "free"—a form of puffery (*26*). Preston (*24*) argues that even a trade name ("Wonder Bread") may be a puff. Under current interpretation of the law, all these statements may be literally "false," but are not prosecuted because they involve matters of individual taste or because it is difficult to establish harm for a substantial minority of rational consumers. Legal reasoning assumes that both buyers and sellers anticipate sellers' hype about their products. That is, obvious exaggeration in advertising is legal partly because advertisers claim (and the law assumes) it is ineffectual.

FTC Unfairness Approach

The "unfairness doctrine" provides an additional and distinct set of criteria for FTC actions under Section 5 (*21*, *22*). Under this legal theory, FTC intervention is justified by practices that offend public policy or public standards of decency, that affect vulnerable consumer groups, or that involve disparity in access to information between sellers and buyers. It is possible that ads based on "socio-psychological representations" (for example, "Coke is it!") that are not strictly deceptive might be subject to regulation under this approach.

The unfairness doctrine was the basis of the "advertising substantiation" form of relief (*30*). Unlike its remedies based on the deceptive advertising theory, the FTC does not have to demonstrate that a claim is false or misleading. Rather, the agency must only show that an unfair practice occurred in connection with an advertising claim. Unsubstantiated advertising cases, beginning with *Pfizer vs. FTC* in 1972, only require that the FTC prove that the advertiser did not have documentation or other evidence as to the truth of a claim regarding the quality, performance, efficiency, safety, or price of its product prior to the time the adverising occurred. Even if a claim is true, an advertisement is considered unsubstantiated if the advertiser has no "reasonable basis" for the claim. The type of substantiation varies according to the type of claim. For example, a statement that a food was kosher could be supported by managers' affadavits or company production records. Claiming that a food was the "lowest in calories," on the other hand, might require evidence of prior literature searches, scientific tests, or a consultant's report. Any plausible interpretation of the claim understood by a significant minority of potential consumers is regarded as a separate claim. Relief in these cases has typically consisted of cease-and-desist orders requiring specific substantiation for similar future claims (see (*16*)). Because most of the evidence in advertising substantiation cases is subpoenaed company records, this approach shifts much of the cost of assembling evidence to the advertisers. The FTC still bears the "burden of proof" in all legal proceedings.

Other Related Public Regulation

At least five other forms of Government intervention aim at correcting market failures arising from advertising. These are regulations covering monopolization, price discrimination, trademarks, grades and labels, and media broadcasting. None of these regulatory activities is considered consumer protection, but all are based in part on the same economic rationale.

Section 5 of the FTC Act has been used together with other antitrust statutes to prosecute monopolization supported by anticompetitive advertising.[8] Two outstanding recent examples are the FTC's cases against the breakfast cereal makers

[8] The first case to use the argument that advertising could have anticompetitive effects was *FTC vs. Proctor and Gamble* (1967), which was brought under Section 7 Clayton Act which refers to mergers.

and against Borden ReaLemon (*17*). In the cereals case, the FTC's counsel argued that excessive product differentiation was the principal cause of blockaded entry in the industry; that is, intense advertising and sales promotion together with preemptive new product introductions were said to be the major business strategies that were monopolizing the industry. Restructuring of the industry and compulsory trademark licensing were the proposed remedies; however, the administrative law judge hearing the case doubted the validity of the "shared monopoly" theory, so he decided in favor of the cereal companies in September 1981.[9] In the ReaLemon case, the commissioners decided that the proposed remedy was too severe and merely directed Borden to cease its predatory pricing.[10] Thus, the FTC has argued that advertising is the root of monopoly in a few recent cases involving food products, but it either has lost the case or has failed to obtain the kinds of novel remedies thought to be necessary.

Another statute that serves as the basis for the FTC's and the Justice Antitrust Division's actions on advertising is the Robinson-Patman Act of 1936 (*9*). About a fifth of FTC actions under this law have dealt with advertising "allowances" given by manufacturers to retailers ostensibly to compensate retailers for advertising expenses related to the manufacturer's product. The FTC was able to establish that in most cases the allowances exceeded actual retailer advertising costs and were thereby a form of discriminatory price cutting. However, the FTC has initiated very few such cases in the last 15 years. In fact, September 1982 congressional testimony by antitrust officials indicates that few Robinson-Patman cases of any kind will be brought in the foreseeable future.

Advertising effectiveness presupposes the existence of a system of legal protection for trademarks and trade names (*36*). Trademarks are registered by the U.S. Patent Office. Like patents, trademarks may constitute legal barriers to entry but, unlike patents, they are indefinitely renewable. Historically, trademarks have been the basis of resale price maintenance, market segmentation, price discrimination, and cartels. Trademarks can be combined with patents to create sustained price premiums; "Formica" and "Xeroxing" are two examples often given in the literature. "Trademark banking," the practice of one company's registering a large number of desirable names for a particular product, is a form of unfair competition if it has the effect of excluding competitors. Potential entrants thus prevented from entering can sue established firms that have "banked" trademarks they do not use.

Trademark infringement suits can be brought under State statutes or under the Lanham Act of 1946 at the Federal level. In addition, the FTC may bring cases to establish that a trademark has evolved into a generic term; "aspirin," for example, was at one time a registered trademark in the United States. (In Europe it is still a trademark of the Bayer company.) Private suits can also be brought. The patent for shredded wheat expired in 1912, but it was not until 1938, after 25 years of litigation that the courts decided (*Kellogg Co. vs. National Biscuit Co.*) that the name was generic.[11]

Several Federal agencies regulate grading, standards of identity, or labeling of products (*3*). The U.S. Department of Agriculture is responsible for those regulations covering processed meat, poultry, and egg products as well as many unprocessed agricultural commodities. The Food and Drug Administration (FDA) has authority over most other processed food products and the Bureau of Alcohol, Firearms, and Tobacco (BAFT) over alcoholic beverages. Government grades are used primarily by commercial buyers and sellers rather than by consumers, but where grading exists it is associated with foods that have low levels of physical product differentiation. Similarly, many foods (ice cream, mayonnaise, and peanut butter) have standards of identity that set minimum ingredient standards. Foods that do not meet the standards must use

[9] The Commission refused to hear an appeal of the case. Because of intense lobbying by the industry, the Congress had directed the FTC to stop spending funds on the case as of October 1981.

[10] In the Borden ReaLemon case (1976), the Government argued that the price premiums commanded by the brand were due to excessive advertising and the dominant market position of the brand. Competitors were disadvantaged by predatory geographic price discrimination. The remedy sought by the complaint counsel and ordered by the administrative law judge was compulsory licensing of the ReaLemon brand.

[11] A more recent case involves the unsuccessful attempt of Phillip Morris' Miller Brewing Co. to argue that its "Lite" trademark rights gave it exclusive use of the term "light" to describe beers.

different generic designations (for example, salad dressing instead of mayonnaise) or be labeled "imitation." Federal labeling regulations insure the accuracy of open dating, nutritional claims, and ingredient lists. Some labeling rules may provide guides to quality for consumers. For example, alcohol levels in wine or spirts that the BAFT requires on labels may aid consumer choice; however, until recently, the BAFT did not permit comparative advertising of alcoholic beverages.[12] In sum, some Federal labeling or grading regulations have reduced the scope for advertising or other forms of product differentiation and have aided consumers in making price-quality comparisons.[13]

Finally, some Federal regulations of advertising affect the broadcast media (*37*). In 1967, the Federal Communications Commission (FCC) issued a rule governing access to and fairness in commercial advertising. This "fairness doctrine," previously applied only to political issues, states that counter-advertising time should be made freely available on important public policy issues. Under that rule, the FCC permitted counter-advertising of cigarette advertisements during 1968-70 (in the ratio of one to three) because it considered the debate on the health effects of smoking a major national controversy. Since 1971, the FCC has monitored the ban on radio and TV advertising of cigarettes (*6*). In 1974, the FCC repudicated its application of the fairness doctrine to commercial advertising, and its change in policy was upheld in a 1975 court case. If the health and safety of certain foods is ever deemed an important enough public policy issue, the cigarette episode will likely be cited as an important precedent.

Regulation by Private Groups

Advertising is voluntarily restricted by some industry groups (*34*). Probably the most important instance of self-regulation is an ethical statement of the American Association of Advertising Agencies entitled "Standard of Practice." This code, which has been endorsed by most of the leading advertising industry associations, restricts its members from producing advertising copy containing:

- False or misleading statements or exaggerations,
- Testimonials that do not reflect the "real choice of a competent witness,"
- Misleading price claims,
- Unfair or disparaging comparisons,
- Insufficiently supported claims or claims that "distort the true meaning or practicable application of statements made by professional or scientific authority," and
- Statements, suggestions, or pictures offensive to public decency.

It is on the basis of this and other codes that the National Association of Broadcasters (NAB) has banned radio and TV advertisements of distilled spirits, although advertising of beer and wines is permitted. Furthermore, the models used in alcholic beverage ads must not appear to be below the legal drinking age and must not be currently active sports figures. The NAB also has certain restrictions on the types and content of candy and breakfast cereal advertisements aimed at children. These and other steps were taken largely to avoid more formal Government regulation of alcoholic beverage advertising, although convictions about corporate social accountability cannot be discounted.[14]

Several State and national advertising groups have programs that arbitrate disparagement or fraud complaints among their members; other organizations attempt to mediate complaints from the public about specific advertising campaigns. The leading national body is the National Advertising

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[12] The current administration is considering the repeal of regulations governing standards of identity. The BAFT was nearly dissolved in 1982 because of the lobbying efforts of the National Rifle Association, among others, and this would have diminished alcoholic beverage labeling regulation.

[13] The Fair Packaging Act of 1966, enforced by the Bureau of Standards, has as its goal to reduce the number of package sizes used in an industry so as to facilitiate consumer price comparisons. The act depends on voluntary industry agreements. One agreement covered breakfast cereal boxes. The advent of unit pricing in many grocery stores reduced the need for this legislation.

[14] In March 1982, the NAB suspended enforcement of its TV and radio codes in response to a U.S. District Court ruling that the portion of the code restricting multiple product advertising in commercials of less than 60 seconds violates the antitrust laws (see *Broadcasting Magazine*, Mar. 15, 1982, p. 45). However, the three major TV networks continue to censor proposed advertisements. *The Wall Street Journal* reported (Sept. 30, 1982) that the networks' 29 censors evaluate about 50,000 different ads per year, rejecting up to 40 percent of the proposed commercials.

Review Board, established in 1970 as part of the Council of Better Business Bureaus.[15]

Consumer groups can affect the impact of advertising. They have been effective in tracking and commenting on advertising regulations proposed by Government agencies. Groups like the Consumers Union publish ratings of foods and other consumer products that sometimes call into question claims of superior quality made by leading manufacturers. Consumers can also form class-action suits where they can prove sustantial economic injury has occurred. These suits have not been widely used as yet for misleading food advertising, as proof of significant harm from food advertising is difficult. Yet, the size of the finds often awarded might make this approach effective (*36*).

The Current Debate

The FTC and similar State agencies win a high proportion of the deceptive or unsubstantiated advertising cases they bring—over 90 percent by one estimate (*36*). There is wide public and official support for the principle of protecting consumers from deceptive advertising. Business and consumer groups alike recognize that fraudulent claims can have serious adverse consequences. There is less agreement as to whether regulation can deal with unfairness arising from specific advertising practices. Differences of opinion also exist over the propriety of specific actions and the efficacy of some remedies.

Critics of FTC activism assert that merely misleading advertising (no fraudulent intent) should be left unregulated because the market will encourage counter-advertising by rival sellers, that affirmative disclosures themselves are sometimes misleading, that regulation reduces the volume of desirable advertising and new products introduced, and that consumers are too rational and well informed to need protection.

During 1980-82, advertising regulation has come under especially sharp criticism. The new chairman of the FTC on his own initiative has proposed severely limiting the number and types of cases initiated (*15*). He would limit challenges to claims that are strictly false and not merely "unfair" or misleading by passing laws that limit the meaning of the terms. Claims about products that are cheap, frequently purchased, and "easily evaluated" by consumers would also not be challenged. Most grocery items fall into this category. Under his proposals, the standard of proof would be raised to require actual (material or monetary) substantial harm to a reasonable consumer. Psychic harm or possible injury to "vulnerable groups" would be largely ignored.[16] Thus, under these proposals, the advertising substantiation program would be ended, no cases would be brought challenging opinions expressed in advertising (for example, "tastes like cola"), and mere omission of relevant facts would not be the basis of a challenge.

Supporters of strong Federal regulation of advertising disagree with the proposed changes (*32*). Some of their objections rest upon questions of legal procedure. A statutory definition of unfairness or deception would replace the traditional method of evolving a set of standards through case law. In fact, such an approach would probably hinder the FTC in acting in exceptional circumstances and would probably reduce the scope of judicial review of FTC decisions. Other objections are based on the suggested criteria for bringing unfairness cases. Several types of vulnerable consumers would no longer be protected; bereaved purchasers of funeral services are one example. The need for establishing that the benefits of restricting an ad outweigh the costs may be onerous, particularly if the costs are mainly psychic. Calculating the harm done to consumers misled by a false claim that a food was kosher or vegetarian might tax the ability of the best social scientist. Finally, it is debatable whether the "reasonable consumer" standard is appropriate. If consumers are indeed swayed by emotive or subconscious appeals in advertising, then consumers almost by

[15] A recent example of how self-regulation works is a 1980 Minnesota TV advertisement for Tony's frozen pizza. The ad in question claimed that all rival frozen pizzas were topped with imitation cheese ". . .made with casein, the main ingredient in some glues." Because it was so effective, the ad won a prize from a local advertising association. However, rival frozen pizza manufacturers complained that the message was misleading. The State's Better Business Bureau was instrumental in stopping the advertisement on the grounds that casein occurs naturally in all dairy products and, therefore, was found in the "real cheese" on Tony's pizzas as well.

[16] The proposed redefinition of unfairness would extend to vulnerable groups only if it could be proved that the advertiser intended to mislead a potential consumer. Proof of intent is often difficult to obtain.

definition never make rational choices. There is no legal concensus as to what constitutes a reasonable response to advertising. The summary judgment of one legal expert is that "A 'free-fire zone' for deceptive advertising would be the inevitable result of adopting Chairman Miller's proposal" (*32*, p. 11).[17]

Even the more ardent supporters of Federal regulation of advertising recognize the complexity of the problem of reducing the harm to buyers while retaining the competitive benefits of advertising. Most of their reservations concern the effectiveness of enforcement, particularly consent decrees that fail as strong deterrents. They contend that correction typically occurs long after the harm is inflicted, with little attention given to followup inspections, and that because only advertisers are prosecuted, there is no deterrent effect on the advertising media themselves. Some FTC supporters question the rationality of the agency's diversion of legal resources toward consumer protection and away from more traditional antitrust enforcement. Others have argued for a significant expansion of the definition of unfair or deceptive practices which the FTC could use in setting its agenda (*25*).

Wilcox and Shepherd (*36*) judge that most observers would probably agree that advertising regulation has raised the level of honesty in national advertising and that the FTC serves as a valuable safety valve for consumers—a sort of national complaint department.

[17] Both sides seem to agree that the Listerine case is one that would be brought under either set of standards. That is, reasonable consumers wasted a lot of money buying Listerine because they wanted to prevent viral infections. However, the Fresh Horizons bread case is one on which the two sides differ. In this case, the claim was made that the bread contained five times as much fiber as regular breads. The FTC challenged ITT-Continental Baking because it failed to reveal that the fiber in their bread was wood pulp. The Commission decided that omission of this information misled consumers about why the bread was allegedly superior. Under the new proposals, a case like Fresh Horizons would not be brought in the first place; even if it were, the FTC would be required to present evidence that wood pulp fiber is nutritionally inferior to grain fiber. A second case about which the two sides disagree is the Kroger Price Patrol case. The critics of current FTC standards argue that the ads were informative about prices and that Kroger did not specifically claim scientific validity. The FTC's defenders counter that there was evidence that Kroger actually had higher overall prices than its rivals (contrary to Kroger's claims) and actual harm was done both to Kroger's rivals through lost sales and to consumers who switched their grocery shopping to Kroger.

Conclusions for Research

Economists have developed and tested numerous models that measure the influence of advertising amounts on market structure and performance (*2*). Moreover, economic analyses have contributed significantly to the design of public policies regarding monopolization, price discrimination, trademarks, grading, and other areas at least tangentially related to advertising regulation (*27*). By contrast, there is a paucity of economic analyses of consumer protection regulations. Although a modest beginning has been made (see papers in *4*), the major difficulty probably lies in a problem common to regulatory assessment—the measurement of benefits. It is noteworthy that the few empirical studies cited by those who favor deregulation deal almost exclusively with price advertising by retailers. Far more relevant, but difficult, for policy information would be analyses of the qualitative content of advertising by manufacturers.

The analytical difficulties do not seem insuperable. For example, it would be possible to measure the price impacts of various advertising regulations cross-sectionally across jurisdictions with different regulations. Alternatively, ample records may exist from hearings on advertising-deception cases to measure the extent of consumer injury due to changes in purchasing patterns or the extent of competitive gains to participating advertisers. The case-study approach could be used to estimate the potential benefits from actions based solely on the deceptiveness theory as compared with actions incorporating the unfairness doctrine.

Several temporal studies might be feasible research topics. For example, one might compare the long-run effects on market shares or prices of the different forms of relief employed by public agencies (consent decrees, case-and-desist orders, TRRs, and so forth). A number of analyses have examined the influence of the cigarette advertising ban, the saccharine warning label, and other advertising regulations on sales or advertising conduct. Should proposed reductions in specific advertising regulations take place, the change may well offer the kind of rare social experiment needed for rigorous hypothesis testing. It would be interesting to measure the response of private markets for information should FTC regulation cease.

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Rank and Salary of Federally Employed Agricultural Economists

By Katherine H. Reichelderfer*

In this age of restricted budgets and reduced hiring, agricultural economists need to understand the workings of the market in which they act as the commodity. This is particularly valuable if individuals can relate personal and professional characteristics to employment and salary potential.

Recent investigations of the agricultural economics labor market have focused on the impact of sex, race, and ethnicity on employment and salary opportunities. Although these issues are important, the studies exploring them are dominated by data from and analysis of the academic sector. They cannot be used to explore these issues in the Federal sector adequately or to address factors unique to Federal employment.

This article reviews recent findings of other researchers as background on current issues. It then gives the results of a survey of a sample of federally employed agricultural economists drawn from ERS, and presents, applies, and discusses the implications of a model which explains salary variation in that sample.

Background

Lundeen and Clauson (*4*), Lee (*2*), Redman (*5*), and Lane (*1*) have reported on the conduct, results, and analysis of a survey to determine the relative opportunities for and status of women in agricultural economics.[1] Lee's multiple regression analysis of factors determining agricultural economists' salaries focuses primarily on a comparison of males and females in the profession, but also considers other determinants of salary. In Lee's model, before-tax 1980 salary is dependent on nine independent variables: educational background (whether or not Ph.D. was received), years since last degree was received, months of tenure in present job, number of professional publications, number of books published, whether or not the individual's position is primarily administrative, number of times unemployed or on extended leave for 6 months or more, percentage of income derived from consulting, and sex of respondent. Lee found this model explained 69.5 percent of variation in salary for a sample of 145 male and female American Agricultural Economics Association (AAEA) members responding to the survey. It performed better, explaining 76.8 percent of variation in salary, for a more homogeneous subsample of 104 respondents with academic employers. In the analysis of academic salaries, the coefficients of books published, career interruptions, and consulting proved to be independently insignificant. The estimated model showed a significant and negative coefficient associated with being female, and it implies that, all else constant, women receive approximately $3,000 less per year than do men in academia. All other significant coefficients are positive and range from $114 per annual professional publication to $12,446 associated with possession of a Ph.D. degree.

Working with data summarized from the 1981 AAEA Employment Registry, Strauss and Tarr (*7*) developed single-equation regression models to relate years of experience, highest degree received, sex, and race/ethnicity to annual salary of agricultural economists employed by each of the following: educational institutions, the Federal Government, State and local governments, the private sector, and miscellaneous and international organizations. They find academicians have lower salaries than do those employed in the other sectors. Possession of a Ph.D. has a significant positive effect on salary in all sectors, but the strength of its contribution is far greater in State and local government and education institutions than in Federal Government or the private sector. Strauss and Tarr find women earn significantly lower salaries in educational institutions and the private sector, but do not find significant differences attributable to sex in Federal or State and local government sectors. With regard to race/ethnicity, they find no evidence that black agricultural economists are disadvantaged in any sec-

*The author is an agricultural economist with the Natural Resource Economics Division, ERS.

[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

tor other than State and local government. But, agricultural economists who indicate they are of Hispanic origin had significantly lower salaries than their non-Hispanic counterparts in academia, and Asian agricultural economists receive significantly lower salaries in all sectors except the Federal Government.

Strauss and Tarr estimated a three-equation multinomial logit model to explain rank and salary as functions of degree quality, experience, sex, and race/ethnicity for 244 academic agricultural economists. Their results suggest that, in spite of observed salary differences, when one accounts for degree quality, sex and race/ethnicity do not significantly affect academic rank or academicians' salary.

Neither Lee's nor Strauss and Tarr's model addresses the possible impact of individuals' primary professional specialty on relative rank and salary. However, the results of the "Survey on the Opportunities for and Status of Women in Agricultural Economics," as reported by Redman (*5*), suggest men and women have made some significantly different choices with respect to their area of specialization within agricultural economics. Lee (*3*) has since found that, according to the way individuals classify themselves in the 1981 AAEA emploment registry, more than 35 percent of the specialties listed by men are in the fields of farm management/production, agricultural marketing, and finance. By contrast, only 17 percent of women listed these specialties, and a substantially greater proportion of women than men classify themselves as specialists in the areas of community and human resources, consumer economics, and general economics.

Recent findings by Stanton and Farrell (*6*) regarding research priorities suggest that the choice of specialty may affect one's rank and salary and partially explain the residual salary differential observed by Lee. Stanton and Farrell surveyed agricultural economics department chairmen and administrators to determine their judgments as to the most important areas toward which work in agricultural economics should be directed. A total of 39 percent of those surveyed indicated commercial agricultural production and marketing as priority research areas. Consumer, welfare, community, and human resource economics were not singled out by program administrators as being among the most important issues. Thus, it is apparent a larger portion of men than women are active in the specialties that are more popular with research program administrators. This finding could have strong implications regarding the mean salaries observed for men and women.

Another variable that can certainly affect professionals' salaries is their observed productivity. Of special interest to many agricultural economists in Government are the possible tradeoffs among staff work, the publication of economic information, and publication of research in recognized journals. Strauss and Tarr were unable to include measures of productivity in their model because full publication records are not reported in the AAEA registry. Lee's publication variable is described by data resulting from a survey question asking, "How many publications have you had in the last 5 years related to your field of specialty?" Respondents' reports of their publication record lumped refereed journal articles, experiment station bulletins, extension publications, working papers, and all other publications one might broadly classify as "professional" into a single category; there was no way to separate or distinguish among various classes of publication. Nevertheless, decisions regarding hiring, tenure, promotion, and merit-based salary increases can be strongly influenced by the distribution of an individual's publications among different specific professional outlets. Accounting for this reality by disaggregating the publication variable into a set of separate variables could greatly influence the results obtained by models of salary determination for agricultural economists.

Current and potential Federal employees may be concerned with additional factors that may affect one's rank and salary. How does making the choice between research and administrative career paths in Government affect earning potential? Is one likely to make more money working in an Agency's headquarters than in a field location? Does the agency, division, branch, or other work unit within which an individual works influence promotion possibilities and salary? These questions are not addressed by recent studies of the agricultural economics labor market.

Federal Employment of Agricultural Economists

In 1981, approximately 18 percent of all agricultural economists listed in the AAEA Registry were employed by the Federal Government. The majority of these individuals (72 percent) worked for USDA (7).

USDA's Economic Research Service (ERS) is the largest single Federal employer of agricultural economists. It was chosen as a case study agency for examination of factors affecting Federal agricultural economists' rank and salary. As of January 1, 1982, ERS employed 526 individuals in its agricultural economist job series. Females comprised 16 percent of that work force, over twice the proportion indicated by AAEA membership lists for the profession overall.

Survey of ERS Agricultural Economists

In February 1982, a survey questionnaire was mailed to a sample of ERS agricultural economists to collect data for a multiple-regression analysis of factors affecting their salaries. The questionnaire covered the following areas: current employment status and employment history with ERS, general educational characteristics, recent (last 5 years) publication record, sex, and perceptions of professional position in relation to members of the opposite sex. As 26 percent of ERS agricultural economists work outside the Washington, D.C. metropolitan area, current geographic location was collected as an employment variable. In an attempt to overcome ambiguity with respect to what constitutes a professional publication, respondents were asked to indicate the number of publications in each of nine specified categories they had authored in the last 5 years. Included as separate, explicity defined categories of publications were the following: refereed journal articles; published research report series, including experiment station bulletins; Situation and Outlook reports; ERS Staff Reports; popular articles; book chapters; and books.

The questionnaire was sent to each of the 82 ERS female employees classed as agricultural economists and to a sample of male employees in the same job series. The male sample was selected in two ways. First, from an alphabetic listing of ERS agricultural economists, their sex, and a salary indicator (GS-grade and step levels), the name of the first male on the list who followed the name of each female and who possessed a GS-level within one step of the female's level, was placed in the sample. Lundeen and Clauson also used a similar matched-sampling procedure. In the ERS study, it yielded 61 names. A separate, random choice of males yielded 135 names, 18 of which overlapped with the matched sample. A combination of the two sets gave a total survey sample of 178 men.

Survey Response and Summary

The total response rate for the sample of 260 employees surveyed was 66 percent, which was evenly distributed among male and female respondents. The respondent sample represented roughly a third of all ERS agricultural economists.

Table 1 shows the characteristics of the sample population. With the exception of respondents' sex, the distribution of responses among professional employment variables is typical of that for the Agency overall. Table 2 shows respondents' salaries for each of various sample groups. Neither the total sample mean salary nor the mean salaries for men and women differs significantly from those reported by the Agency for its GS-110 series (the economists' professional job series) as of the start of 1982. For these reasons the sample can be regarded as representative of the total population.

One can make a number of observations from examination of tables 3-5, and I encourage readers to study these according to their own special interests. Here I review only a few differences in respondent charactersitics that may affect the salary differences shown in table 2. The average tenure with ERS, years since highest degree, proportion of respondents with a Ph.D., and percentage of responsdents with management or administrative responsibility are greater for NRED than for the other divisions. These factors may explain the finding that the average NRED respondent's salary is also highest among divisions. By contrast, EDD and IED respondents have received their highest degrees and been employed with ERS for shorter periods of time; these factors may explain the relatively lower mean salaries for those subsamples. The typical individual located in the field is likely

Table 1—Selected characteristics of ERS survey respondents

Characteristic	Proportion of respondents
	Percent
Duty station:	
Washington based	70
Field staff	30
Sex:	
Male	68
Female	32
ERS division:	
National Economics (NED)	39
International Economics (IED)	25
Natural Resource Economics (NRED)	26
Economic Development (EDD)	10
Education (highest degree):	
B.S. or M.S., economics or agricultural economics	50
B.S. or M.S., other	10
Ph.D., economics or agricultural economics	38
Ph.D., other	2
Job responsibility:	
Primarily research	84
Primarily management/ administration	16
GS level:	
GS 5-7	6
GS 9-11	27
GS 12	26
GS 13	25
GS 14	11
GS 15	5
Work week:	
Full-time	95
Part-time	5

to have more experience and a higher degree than a Washington-based employee, thus earning a greater salary. Finally, we see that the majority of female employees have been with ERS for less time and, on the average, the female employees do not possess the same level of educational training as does the male subsample.

The measure of perception of sex disadvantage is determined by yes/no responses to the survey

Table 2—Mean salary of survey respondents, by duty station, sex, ERS division, and job responsibility

Sample group	Mean annual salary[1]
	Dollars
Duty Station:	
Washington based	31,484
Field staff	35,733
Sex:	
Male	35,928
Female	25,999
ERS division:	
National Economics	34,534
International Economics	29,530
Natural Resource Economics	35,127
Economic Development	28,331
Job responsibility:	
Primarily research	30,923
Primary management/ administration	43,914
Total sample	32,751

[1] Salary based on respondents' grade and step levels as reported on completed questionnaire.

question: "Do you think you are paid less, have a lower job level, or fewer career advancement opportunities than you would if you were of the opposite sex?" The proportion of positive responses to this question does not differ significantly between field and Washington-based staff, and differs slightly among divisions. The largest difference in perception occurs between male and female employees: more women than men perceive sex discrimination.

Analysis of Factors Affecting ERS Agricultural Economists' Salaries

A model was estimated from the survey data to determine the degree to which various characteristics affect federally employed agricultural economists' salaries and to provide a basis for testing the accuracy of perceptions regarding the impact of these factors on salary. Accordingly, the dependent variable in the model is the before-tax, annual, fiscal year 1982 salary indicated by survey respon-

Table 3—Selected characteristics of survey respondents, by ERS division

Characteristic	Unit	Division[1]			
		NED (N = 68)	IED (N = 44)	NRED (N = 45)	EDD (N = 18)
Respondents located in field	Percent	22	9	64	28
Female respondents	do.	28	41	20	56
Respondents with Ph.D.	do.	40	30	47	44
Respondents primarily managers/administrators	do.	15	14	20	11
Respondents receiving highest degree while in ERS	do.	23	23	33	44
Average tenure in ERS	Years	9.7	6.2	12.3	5.1
Average time since highest degree	do.	10.9	7.0	11.3	5.4
Average time between promotions	do.	3.8	2.8	3.9	2.0
Average total publications per year (all types)	Number	4.1	4.3	2.6	3.3
Respondents perceiving sex disadvantage	Percent	25	32	36	33

[1] NED is the National Economics Division; IED is the International Economics Division; NED is the Natural Resource Economics Division; and EDD is the Economic Development Division. These four divisions employ the vast majority of economists in ERS. No survey responses were received from the Data Services Center. Two responses received from individuals employed by the Administrator's Office (one an administrator; one a nonadministrator) were classified as NED employees for the purpose of this tabulation.

dents' GS-grade and step levels. Independent variables tested as possible determinants of salary were:

1. Educational background—with Ph.D. = 1, otherwise = 0;

2. Experience—(a) months since highest degree was received; (b) tenure (months) with ERS;

3. Administrative duties—administrator = 1, otherwise = 0;

4. Geographic location—stationed in Washington, D.C. = 1, all field locations = 0;

5. Research productivity—(a) number of refereed journal articles published per year over last 5 years (or, if less than 5 years, annual average since receiving highest degree); (b) sum of all other professional papers and reports per year over last 5 years;

6. Sex—female = 1, male = 0;

7. Career interruptions—number of times unemployed or on extended leave for 6 or more consecutive months;

8. Area of specialization indicated by ERS division in which individual is employed—National Economics Division = 1, all other divisions = 0.

The geographic location variable was included to test a popular impression that, all else equal, Washington, D.C.-based personnel receive higher pay. The possible contribution to salary of subject area (NED work, as opposed to that in NRED, IED, or

Table 4—Selected characteristics of survey respondents, by duty station

Characteristic	Unit	Washington based (N = 122)	Field staff (N = 53)
Female respondents	Percent	38	19
Respondents primarily managers/administrators	do.	16	15
Respondents receiving highest degree while in ERS	do.	24	38
Average tenure in ERS	Years	7.6	12.2
Average time since highest degree	do.	8.8	11.0
Average time between promotions	do.	3.0	4.3
Average publications per year (all types)	Number	3.9	2.9
Respondents perceiving sex disadvantage	Percent	31	28

Table 5—Selected characteristics of survey respondents, by sex

Characteristic	Unit	Male (N = 119)	Female (N = 56)
Respondents with Ph.D.	Percent	48	21
Respondents primarily managers/administrators	do.	18	11
Respondents receiving highest degree while in ERS	do.	32	20
Tenure in ERS	Years	11.5	3.8
Average time since highest degree	do.	11.8	4.5
Average time between promotions	do.	4.2	1.6
Average publications/year (all types)	Number	3.8	3.3
Respondents perceiving sex disadvantage	Percent	26	39

EDD) was tested because NED's objectives correspond more closely to the categories of issues reported by Stanton and Farrell perceived to be highest priority areas of research.

Regression results are shown in table 6. The coefficients of variables describing geographic location and career interruption proved highly insignificant.[2] The coefficient measuring journal publication record also proved insignificant. However, the coefficient describing publications exclusive of journal articles indicates a positive, significant contribution to annual salary of total research output.[3] Possession of a Ph.D., months since receiving highest degree, length of tenure with ERS, employment within NED, and assignment of administrative duties all prove to be strong, positive, significant contributors to one's salary. The negative coefficient associated with the sex variable is insignificant.

It should be noted that the analysis and the results reported above apply only to ERS economists in grades 9-15. Although 10 observations from survey response by agricultural economists in grades 5-7 were available, these were not included in the model.

Interpretation and Discussion

The model's results suggest the salary received by federally employed agricultural economists is a function of experience, education, subject matter responsibility, and productivity, but is not affected by individuals' sex or duty station location. Individuals who have accepted managerial or admin-

[2] We ran a backwards, stepwise regression by deleting variables for which coefficients were found to be insignificant, in order of degree of insignificance. At no stage of the stepwise deletion of the four insignificant variables did the level of significance of remaining variables' coefficients change by as much as 1 percent. Thus, the variables may correctly be assumed independent of one another, and the coefficients describing the effects of location, career interruption, journal publication, and sex all prove insignificant at levels of 70 percent or less.

[3] Alternative model specifications were run to test the contribution of each of the nine publication categories on which observations were collected. No single category of publications proved a significant contributor to salary. However, when all publications including journal articles were lumped into a single variable, a coefficient of $177.79, with a t-value of 2.06 was derived, and coefficients of all other variables remained approximately the same as those shown in table 6.

Table 6—Regression results for sample of ERS agricultural economists

Variable	Estimated coefficient
Intercept	21,994.22 (22.25)
Ph.D.	6,980.82 (9.14)
Journal articles per year	399.58 [1](.71)
All other publications per year	164.82 (1.78)
Months since highest degree	18.90 (3.90)
Tenure with ERS (months)	41.09 (6.99)
Washington, D.C., location	146.02 [1](.19)
National Economics Division	1,581.21 (2.26)
Administrator	7,177.11 (7.20)
Career interruptions	-116.23 [1](.15)
Sex (female = 1; male = 0)	-856.48 [1](1.03)
F	71.38
R^2	.810
Number of observations[2]	161

Note: Numbers in parentheses are t-values (absolute value). Unless designated otherwise, coefficients are significant at a 95-percent level or more.

[1] Coefficient is statistically insignificant at a 70-percent level or less.

[2] Observations comprise the full set of completed responses to the ERS survey by individuals in professional levels (GS-9 through GS-15) of the Federal economist job series.

istrative responsibility receive economic rewards that make the largest single contribution to a Federal agricultural economist's salary.

Possession of a Ph.D., although the most highly significant independent variable in this, Lee's, and Strauss and Tarr's analyses, seems to contribute almost twice as much to academic salaries as it does to ERS professional salaries. This finding most likely reflects differences in the missions of the institutions—particularly the relative focus on teaching and state-of-the-art research, where a Ph.D. is highly desirable, versus providing timely economic intelligence, where one's formal analytical training has less relevance. The difference in mission may additionally explain the relatively higher level of significance associated with the current job tenure variable in the ERS-based model. Timely provision of useful economic information requires the experience and subject matter knowledge that accumulate through tenure in a job. The products of such work also may not be appropriate for publication in research journals. Thus, it is not surprising that journal publication is found insignificant, whereas total publication record is important in determining ERS agricultural economists' salaries.

Inclusion of a proxy variable for area of specialization in the ERS model helped to more fully explain salary differences among individuals, but the location variable did not increase the model's explanatory power. Because locational considerations are technically not supposed to affect rank or salary and because all ERS employees, regardless of location, are restricted to identical pay scale and merit increase requirements, this finding, too, is not surprising.

Perceptions regarding the impact of one's sex on rank and salary conflict with the analytical results. Although the model results imply no significant salary differential between male and female professional employees, over 30 percent of the ERS economists sampled responded they perceived a gender-related disadvantage. This finding suggests there may be a fairly sizeable gap between perception and reality.

Conclusions

This study suggests that Lee's (1981) conclusion that "significant salary differentials between men and women exist after accounting for education, experience, research productivity, and other variables" should not necessarily be interpreted as having broad application to the profession of

agricultural economics. It further implies that with regard to individuals' sex, the establishment of equal opportunity programs in Government, coupled with provisions of the Civil Service Reform Act, has been successful in restricting salary considerations to professional qualifications and performance. On the basis of these findings, new entrants to the agricultural economics labor market can be advised not to enter the market carrying with them a presumption of the wide existence of sexual discrimination.

Findings regarding the strong contribution of a Ph.D. to salary potential also have implications for students and other participants in the agricultural economics labor market. Those who currently perceive that degree as a "white elephant" should be advised, a Ph.D. does currently seem to yield higher income in this profession.

Finally, for those agricultural economists who already possess a Ph.D. and are employed in the Federal Government, this study suggests that as they maintain employment with the Government, continue to produce published output, and adopt managerial or administrative duties, they can expect commensurate increases in salary.

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The Negative Income of Small Farms

By Roger P. Strickland*

One-third of U.S. farms have sales of less than $5,000. In the aggregate, these farms consistently have a negative net income from their production activities (table 1).[1] The inclusion of this size class in the all-farm statistics for 1981 reduced the total returns to operators by over 14 percent and returns to operators per farm by over 44 percent (*2*).[2] It distorts statistics necessary for farm income and financial analysis. The purpose of this article is to examine the impact of including farms with sales of less than $5,000 in the aggregate U.S. Department of Agriculture (USDA) income and financial statistics and to suggest alternative criteria for defining a farm.

Census Definition of a Farm

The current definition of a farm that both USDA and the Census Bureau use for gathering statistics is "any place from which $1,000 or more of agricultural products were sold or normally would have been sold." A decision as to whether establishments in a particular sales class should be defined as commercial farms might instead be based on a financial analysis of the "profit motive" of the average or typical establishment of that size. Criteria based on the operator's motives would be difficult to apply by establishment, but a judicial assessment of a sales class seems feasible. If the conclusion reached is that the representative establishment is consistently operated to make a profit, then that sales class should clearly be included in aggregate farm income statistics. If such a conclusion is not reached, then a strong case can be made for excluding that sales class from aggregate farm income statistics purported to represent commerical producers.

Table 1--Selected income statistics for farmers with sales of less than $5,000

Item	Year			
	1978	1979	1980	1981
	Thousands			
Farms	974	889	854	[1]843
	Million dollars			
Transactions summary:				
Gross receipts	2,746	2,626	2,363	2,527
Total receipts[2]	5,219	5,006	5,170	5,526
Returns to operators	-2,473	-2,380	-2,807	-2,999
Off-farm income	15,205	16,878	17,710	18,836
Balance sheet. January 1:				
Assets	85,966	75,578	81,215	85,916
Debt[3]	11,605	9,965	10,389	11,119
Equity	74,361	65,613	70,826	74,797

[1] Equal to 34.6 percent of all farms.
[2] Expenses for intermediate products, capital consumption, taxes, interest, wages to hired labor, and net rent to all landlords for farm production purposes only.
[3] Includes Commodity Credit Corporation loans and excludes household income such as the imputed rental value of the operator's dwelling.
Source: (*2*, tables 47-50).

The consistently negative net income or returns to operators reported by USDA for the less-than-$5,000 sales classes may exist for two reasons.[3] First, a farm may be in this group temporarily because of recent adverse conditions; hence, the business enterprise will either return to profitability or cease to operate. Second, the composition of this group is relatively stable, and farm profits are not typically the principal reason for existence.

*The author is an agricultural economist with the National Economics Division, ERS. He wishes to thank Allen Smith, Richard Simunek, and two anonymous reviewers for their suggestions.

[1] In this article, the terms "returns to operators" and "farm income" are used interchangeably to represent income from the production of agricultural commodities. Household-based income and expense items such as "imputed value of operator dwelling" and "cost of operating the farm household," which are included in USDA's net farm income series, are not included in returns to operators.

[2] Italicized numbers in parentheses refer to items in the References at the end of this article.

[3] The smallest class reported has sales of less than $2,500, and the next smallest class has sales of $2,500-$4,999.

If a farm-like establishment does not exist principally to profit from agricultural production, then two key questions are: "Why does it exist?" and "Why does it produce and sell any agricultural commodities?" An important followup question is whether the decision leading to the creation and existence of the establishment and the decision to produce and sell agricultural commodities are independent; that is, "Are the objectives different, or are the decisions made at different times?"

A plausible reason for the existence of not-for-profit, farm-like establishments is to provide the amenities of rural living—including privacy and spaciousness, avoidance of air and noise pollution, fresh home-grown food, and recreational activities (including horses). Once a farm-like establishment exists, realizing its financial potential, by supplementing income from nonfarm sources with income from the production and sale of agricultural commodities and with reductions in income tax liabilities, becomes a logical extension. Individual farm income-producing activities may have to at least recover variable costs, but the establishment itself need not be profitable.

Another reason for the existence of unprofitable small farms is the potential for sheltering nonfarm income from taxes. Interest and property taxes are automatically deductible, but a firm could realize additional tax-sheltering benefits only by causing other outlays to be treated as business expenses for purposes of computing State and Federal taxes. Potentially the largest, and thus the most important, tax-sheltering "business" expenses are generally depreciation and associated tax credits from the purchase of buildings, equipment, and vehicles.

IRS Definition of a Farm

The Internal Revenue Service (IRS) generally uses the criterion that a business must show a profit 2 out of 5 years as a rule-of-thumb in its selection of tax returns for audit and its consideration for possible disallowance of business expense claims. A firm that declares a profit in less than 2 out of 5 years can avoid disallowance of business expenses by convincingly demonstrating that it was operated solely to earn a profit. But, an establishment that consistently meets the 2-out-of-5-year rule is unlikely to have its motives questioned. IRS does not insist that the cumulative annual income reported over time be positive.

The same rules apply to all farms regardless of size, and all operators can be expected to take full legal advantage of them. The difference is that establishments dependent on agricultural production as the primary source of their cash flow cannot consistently incur a deficit. Even though they may recover as much as half the deficit in taxes refunded or avoided on income from nonfarm sources, they still must fund the balance. This is not to say that all small farmers get most of their income from off-farm sources and that all large farmers do not. See table 2 for a comparison of the average returns to operators from farm sources and off-farm sources by sales class.

If the typical farm in the less-than-$5,000-sales class is operating more for tax advantages than for agricultural earnings, it can be expected to control its income and expense situations both to maximize the tax-sheltering effects and to meet the IRS's 2-out-of-5-year rule. The tendency would be to report losses in 3 out of 5 years and to report only small profits in the remaining 2 years, with the average reported profit being less than the average reported loss. The consequence would be a negative aggregate farm income for the group as a whole.

Effect of Definition on Financial Statistics

The inclusion of those establishments with sales under $5,000 in the per farm statistics for the all-farm sales class affects the various statistical attributes in terms of magnitude and even direction of change (table 2). For example, in 1981, the inclusion increased both the number of farms (53 percent) and the average off-farm income (26 percent). It decreased the average value per farm of the following financial attributes: assets (28 percent), debts (30 percent), equity (28 percent), gross receipts (34 percent), total expenses (32 percent), and returns to operators (44 percent).

The varying magnitudes and direction of these effects changed relationships and ratios computed when the financial attributes were applied. For

Table 2—Selected financial and operator income statistics, by value of sales class, 1981[1]

Item	Less than $5,000	$5,000-$9,999	$10,000-$19,999	$20,000-$39,999	$40,000-$99,999	$100,000-$199,999	$200,000 and over	All farms	$5,000 and over
					Thousands				
Farms	843	335	286	278	396	186	112	2,436	1,593
					Dollars per farm				
Transactions summary:									
Gross receipts	2,998	9,042	17,437	34,212	73,975	157,876	674,750	63,334	95,263
Total expenses[1]	6,555	12,316	20,448	36,791	70,929	140,812	505,455	56,083	82,293
Returns to operator[2]	-3,558	-3,275	-3,010	-2,579	3,045	17,065	169,295	7,251	12,970
Off-farm income	22,344	18,418	14,021	10,165	8,543	11,753	17,125	16,146	12,864
Balance sheet, January 1:									
Assets	101,917	153,370	226,682	359,403	605,864	1,041,118	2,211,196	403,639	563,308
Debts[3]	13,190	20,603	31,885	53,014	93,452	170,683	468,741	66,967	95,426
Equity	88,727	132,767	194,797	306,388	512,412	870,435	1,742,455	336,672	467,882

[1] Expenses for intermediate products, capital consumption, taxes, interest, wages to hired labor, and net rent to all landlords.
[2] Assumes one operator per farm.
[3] Includes Commodity Credit Corporation loans.
Source: (*2*, table 50).

example, two key financial statistics are the ratio of operator returns to equity, which permits us to compare the current operation's earnings relative to the opportunity costs of the equity capital, and the ratio of debt to operator returns, which indicates how much debt each dollar of profit must support. The all-farm group (current definition) and the over-$5,000 group have operator's returns-to-equity ratios of 0.022 and 0.028 and debt-to-operator-returns ratios of 9.24 and 7.36, respectively. These differences may appear small, but they represent a change of 27 percent in the former ratio and 20 percent in the latter.

The preceding discussion may appear to suggest changing tax laws, but that is not the point. Whatever the threshold established as the minimum farm size, there will be farms at the margin whose profit motives are questionable. The total income sheltered is relatively small, particularly in view of the resources that would be required to evaluate and to litigate the profit motives of the numerous establishments.

A recent USDA publication concludes that farmers do frequently alter management practices to take advantage of tax preferences (*1*). The authors note that in a tax-favored industry such as agriculture, with its use of cash accounting, the annual returns on investment consist of the commercial return from the sale of commodities produced and the returns from the management of tax assets and liabilities. The authors contend that the tax system not only enhances the earnings of farm investors and operators, but also that the tax advantage is frequently more certain than the return from production. Unfortunately, they do not sort out the response by sales class.

A greater degree of certainty, of course, translates directly into an enhanced value being placed on the benefits, relative to those having a higher degree of risk. This situation holds true for farm operations of all sizes, but those in the under-$5,000-sales group are distinct in that tax benefits may overshadow commodity production benefits.

Summary

In 1981, farmers with sales of less than $5,000 sold only $2.53 billion worth of agricultural commodities out of a total of $154.28 billion (table 3). Thus, this smallest third of all farms sold only 1.6 percent of the Nation's total agricultural pro-

Table 3—Number of farms, gross receipts, and net returns to operators, by value of sales class, 1978-81

Year	Sales class							
	Less than $5,000	$5,000-$9,999	$10,000-$19,999	$20,000-$39,999	$40,000-$99,999	$100,000-$199,999	$200,000 and over	All farms
	Thousands							
Farms[1]	843	335	286	278	396	186	112	2,436
	Million dollars							
Gross receipts:								
1978	2,746	2,908	5,214	10,035	25,590	21,269	51,429	119,192
1979	2,626	2,962	5,036	9,669	27,970	26,472	67,055	141,791
1980	2,363	2,775	4,615	8,831	26,745	26,402	67,740	139,471
1981	2,527	3,029	4,987	9,511	29,294	29,365	75,572	154,281
Net returns:								
1978	-2,473	-362	143	1,015	4,636	4,679	14,392	22,031
1979	-2,380	-527	-66	695	4,623	5,576	18,798	26,719
1980	-2,807	-1,007	-795	-652	1,057	2,682	15,083	13,561
1981	-2,999	-1,097	-861	-717	1,206	2,174	18,961	17,663

[1] Existing in 1981.
Source: (*2*, tables 47-50).

duction. The smallest third consistently exhibits negative returns to operators in excess of $2 billion, more than 14 percent of the earnings of larger farms in 1981.

The inclusion of these many small establishments in the official definition of a farm distorts both data collection and analysis related to the commercial production of agricultural commodities. Funds expended to collect and tabulate data from these small establishments would have a higher marginal return if redirected to those farmers who produce and sell 98 percent of the commodities. Redirection could take the form of a substantial increase in sample size and the collection of additional and useful statistics about each establishment.

The definition of a farm is a sensitive subject, and efforts to change it often generate controversy. Under some Federal programs such as the Hatch Act, funds are allocated to the States by means of formulas that include the number of farms.

Thus, a change in farm definition unavoidably creates winners and losers. But, the current definition includes far too many establishments that contribute little to the Nation's total agricultural production. If changing the definition is deemed not to be a feasible alternative at this time, then at the very least, these smaller establishments should be segregated within the data base when people analyze and formulate public policy for commercial agriculture.

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(2) U.S. Department of Agriculture, Economic Research Service. *Economic Indicators of the Farm Sector: Income and Balance Sheet Statistics, 1981.* ECIFS 1-1. Aug. 1982.

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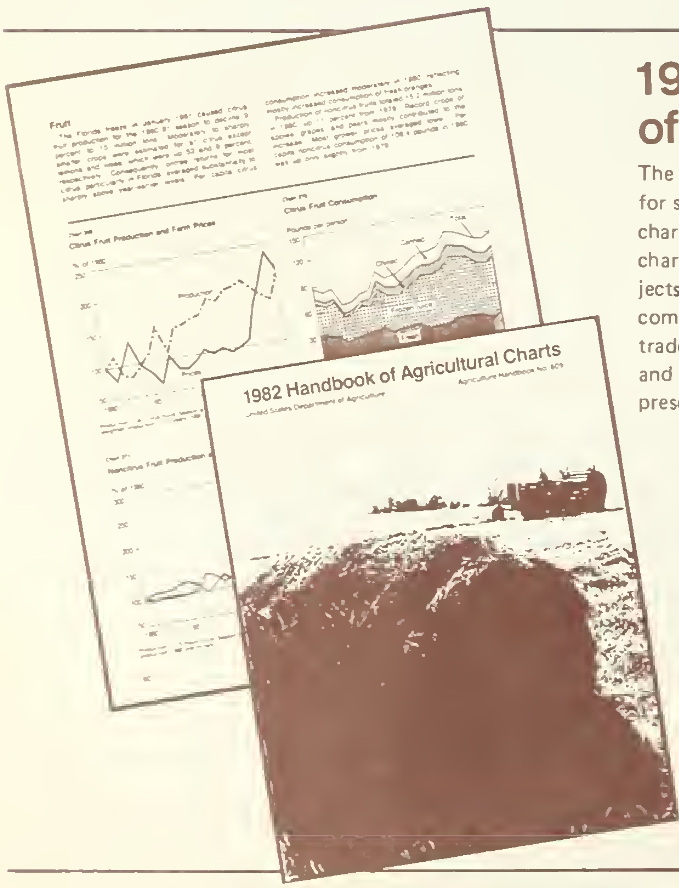

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